ECONOMIC BOTANY

Devoted to Applied Botany

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Federal Plant Introduction—A Review
W. A. Orton and C. O. Erlanson

Bamboo in the Economy of Oceania
R. F. Fox and A. McCurdy

Yerba de la Flecha (Arrow-root) and Related American Species
C. D. Kelly

Utilization of Lichens in the Arctic

The First Decade—Articles and Abstracts
Volumes 1–10

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Federal Plant Introduction—*A Review*[1]

In 1898 the U. S. Department of Agriculture began importation of economically important plants for possible cultivation and utilization in the United States. Since then nearly a quarter million introductions have been made, including the hard winter wheats which today are grown annually on some 27 million acres, and soybeans which now support a billion-dollar industry.

W. H. HODGE AND C. O. ERLANSON[2]

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Introduction of plants from one region to another, from the wild into cultivation, is as old as agriculture itself, and it will continue as long as man moves about the surface of the earth. The curious, the beautiful and the useful plants that have been found in all corners of the globe have been carried by man from place to place, some to find a new home and many to die either because of man's ignorance as to their needs or the plant's inability to withstand a different environment.

Agriculture in the United States is based on the best plants and crops that can be grown under its conditions. Most of the basic stock came from elsewhere, and from this foreign material we have evolved strains and varieties by selection and breeding to fit the needs of our environment. But the gains in production made in the last few decades have shown us how far we are from perfection in any crop; the discovery of new industrial uses has demonstrated how much is yet to be learned of agricultural possibilities; and the disastrous havoc of plant disease, which costs us many millions per year, indicates much room for improvement. These are only a few of the reasons which make it imperative that the agriculture of every State in the Union be constantly supplied through plant introduction with new materials for trial, and that reservoirs of basic plant material be maintained to supply the needs of the plant breeder. This task is one which is beyond the realm of any single individual or any State and hence is one which has long been handled as a Federal service by the United States Department of Agriculture.

[1] Some parts of this article appeared in the writers' "Plant Introduction as a Federal Service to Agriculture" cited in the list of references. The present article is intended for a different group of readers.

[2] Plant Introduction Section, Horticultural Crops Research Branch, Agricultural Research Service, United States Department of Agriculture, Beltsville, Md.

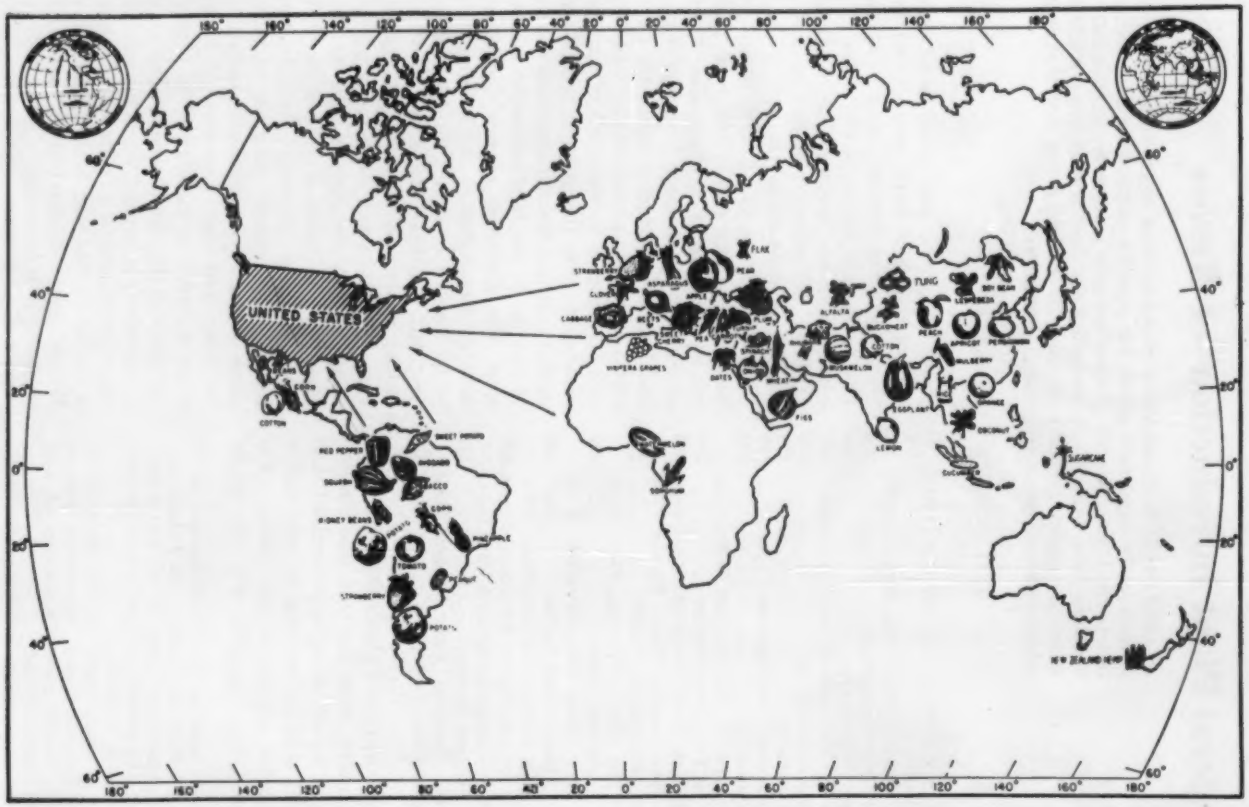


FIG. 1. The world's contributions to the agriculture of the United States.

HISTORY OF PLANT INTRODUCTION AS A FEDERAL PROGRAM

Although a formalized program for plant introduction has been conducted by the United States Department of Agriculture only since 1898, informal plant introduction activities were carried on by the Government throughout much of its early formative years. It was natural that pressing problems of a political nature should first occupy the minds of Government officials, but even in the colonial period such men as Benjamin Franklin made it a point to send home seeds and cuttings of promising plants for establishment in America.

Franklin's example set a precedent which was followed after the Revolution by many consular and naval officers abroad. The practice was officially recognized in 1827 during the administration of President John Quincy Adams who requested that all U. S. consuls forward rare seeds and plants to Washington for distribution. This practice is still continued by officers of the Foreign Service, who frequently serve as important cooperators in the task of plant introduction.

The problem of distributing early plant introductions was solved, in part, in 1836 when Henry L. Ellsworth, Commissioner of Patents, took the initiative and started sending introduced seeds to American farmers, using the franking privileges of Congressional colleagues. Thus began informally a Congressional Seed Distribution program which was to grow eventually to enormous size and was to last nearly a century (until 1925). In 1839 Congress appropriated $1,000 to aid Ellsworth and his Patent Office in certain kinds of agricultural activity, including the handling of introduced seeds. In the years that followed, despite the irregularity of appropriations but largely through the zeal of the Commissioner, the sending out of introduced seeds continued. In one single year more than 30,000 seed packets were given out. Finally in 1847 appropriations for this general program became an annual event, permitting even more active experimentation on the establishment of potential new crops. This phase of the work is indicated by the investigations initiated in 1856 on the cultivation of sorghum and tea. Shortly thereafter, in 1862, during Lincoln's administration, the United States Department of Agriculture finally came into being.

From the above it is evident that plant introduction and seed distribution were among the first agricultural activities of the Federal government. Actually these activities contributed greatly to the formal organization of the Department of Agriculture. Plant Introduction activity is specifically mentioned in the Organic Act of 1862 enacted by the 37th Congress for the formation of the Department. A Commissioner of Agriculture, Isaac Newton, headed the new department, and among other things he was directed " to collect, as he may be able, new and valuable seeds and plants; to test, by cultivation, the value of such of them as may require such tests; to propagate such as may be worthy of propagation, and to distribute them among agriculturists ". This was a reiteration of the powers of Ellsworth's old Agricultural Division in the Patent Office. Even today, nearly a century later, these remain the basic objectives of the Federal plant introduction program.

It was not until the end of the century, when the Department's head attained cabinet rank as Secretary of Agriculture, that larger Congressional appropriations for agriculture were received. One of the results was increased and more efficient departmental functions. Under such favorable circumstances, in 1898 under Secretary of Agriculture James Wilson, there was finally created a " Section of Seed and Plant Introduction ", whose duties it was to centralize for the Department of Agri-

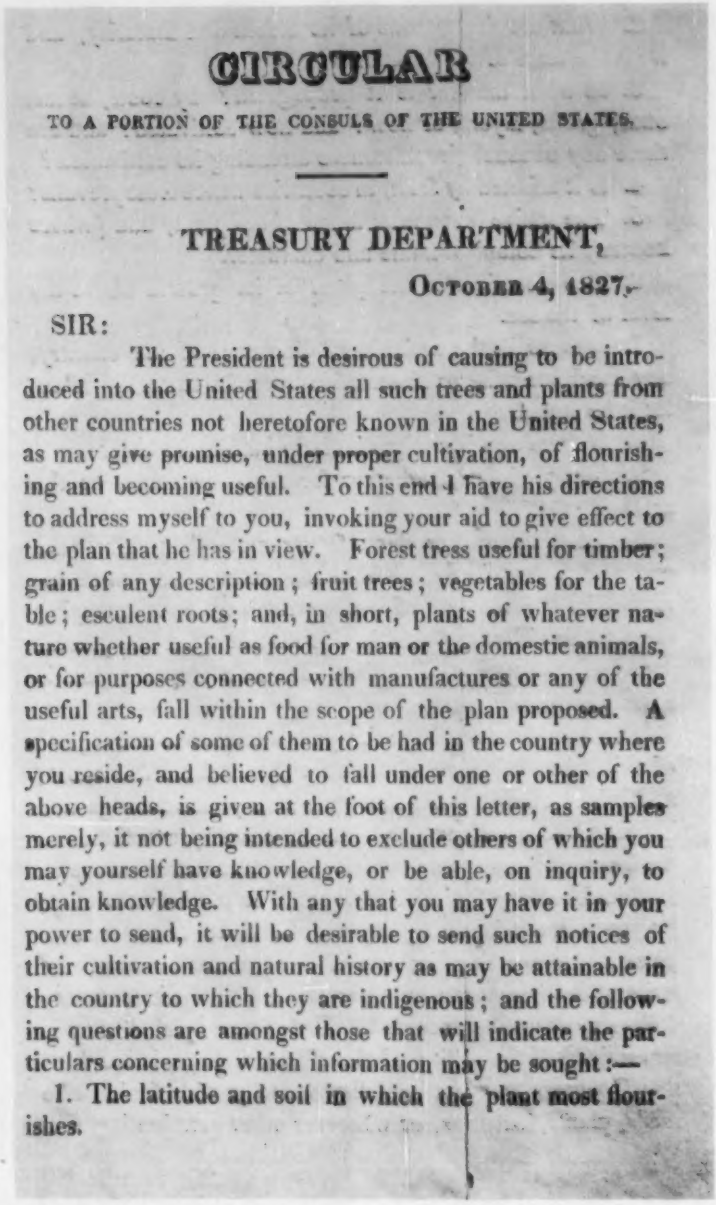
culture all activities having to do with the sustained program of plant introduction. Almost at once, under the aegis of the new Section, experts—including Niels Hansen, Mark Carleton and David Fairchild—were sent abroad for purposes of plant exploration. So successful were they in adding to the agricultural wealth of the country that the plant introduction program received immediate prestige.

In the years since it was established, the original "Section of Seed and Plant Introduction" of 1898–1903 has been known under variants of the same name, including "Office of Seed and Plant Introduction" (1904–1907), "Office of Foreign Seed and Plant Introduction" (1908–1925), "Office of Foreign Plant Introduction" (1926–1930), "Division of Foreign Plant Introduction" (1931–1933), "Division of Plant Exploration and Introduction" (1934–1953), and finally, dating from late 1953, the present name, "Section of Plant Introduction", which today essentially brings the nomenclature back to the original form created in 1898. Despite the name changes the functions of the plant introduction unit of the U.S.D.A. have remained essentially the same throughout the half century of its operation.

At the time of its establishment in 1898 the Section of Seed and Plant Introduction had not yet been given all the duties which were to come to it later. According to the Annual Report of the Secretary of Agriculture for 1900, its early job was "to bring into this country for experimental purposes any foreign seeds and plants which might give promise of increasing the value and variety of our agricultural resources". In addition, in 1898, the Section also had been assigned the task of distributing all foreign seeds that it introduced. These went primarily to the State Agricultural Experiment Stations or to reliable cooperators. But "the distribution of vegetable, flower, and field seeds" fell in the jurisdiction of another agency, the Seed Division, whose primary duty was the handling of the politically important Congressional seed distribution. For purposes of coordinating all seed-distributing activities of the U.S.D.A., in 1898 the new Section of Seed and Plant Introduction and the older Seed Division were placed under the supervision of the Assistant Secretary of Agriculture. The next year Plant Introduction was attached to the Division of Botany "in order to avoid multiplicity of supervision", but on July 1, 1901, it was incorporated in the newly-founded Bureau of Plant Industry (later the Bureau of Plant Industry, Soils, and Agricultural Engineering). In the years that followed, several of the older Divisions were absorbed by the Plant Introduction unit, including the Division of Botany as well as Congressional seed distribution.

Since 1898 some dozen individuals have been nominally "in charge" of the Federal plant introduction unit, but in actuality the work down through the years has been administered principally by four men—David Fairchild (1903–1928), Knowles A. Ryerson (1928–1934), B. Y. Morrison (1934–1949), C. O. Erlanson (1949 to present).

The plant introduction activity of the first quarter-century is inevitably associated with David Fairchild, for it was under his supervision that the general framework of the plant introduction organization as we know it today was established. The work of that period is relatively well-known, having been reported upon informally by Fairchild in several delightful volumes whose titles are familiar to many (see "Selected References"). Fairchild entered U.S.D.A. service (Division of Plant Pathology) in 1889. His was the impetus, aided by that of his friend and co-worker, Walter T. Swingle, which helped organize the original Section of Seed and Plant Introduction during the period 1897–1898.



CIRCULAR

TO A PORTION OF THE CONSULS OF THE UNITED STATES.

TREASURY DEPARTMENT,

October 4, 1827.

SIR:

The President is desirous of causing to be introduced into the United States all such trees and plants from other countries not heretofore known in the United States, as may give promise, under proper cultivation, of flourishing and becoming useful. To this end I have his directions to address myself to you, invoking your aid to give effect to the plan that he has in view. Forest tress useful for timber; grain of any description; fruit trees; vegetables for the table; esculent roots; and, in short, plants of whatever nature whether useful as food for man or the domestic animals, or for purposes connected with manufactures or any of the useful arts, fall within the scope of the plan proposed. A specification of some of them to be had in the country where you reside, and believed to fall under one or other of the above heads, is given at the foot of this letter, as samples merely, it not being intended to exclude others of which you may yourself have knowledge, or be able, on inquiry, to obtain knowledge. With any that you may have it in your power to send, it will be desirable to send such notices of their cultivation and natural history as may be attainable in the country to which they are indigenous; and the following questions are amongst those that will indicate the particulars concerning which information may be sought:—

1. The latitude and soil in which the plant most flourishes.

Fig. 2. The title page of the historic Treasury Department circular, issued at the behest of President John Quincy Adams, requesting the aid of U. S. consular officers abroad in the procurement of plants for introduction purposes.

Fairchild served the Section successively as agricultural explorer (1898–1903), as administrator in charge (1903–1928), and, after retirement, as collaborator (1928–1954). Although an enthusiastic promoter of plant introduction activities, he nevertheless disliked the related administrative duties and much preferred to be in the field. Undoubtedly it was because of this that associates like O. F. Cook (1898–1900), Jared G. Smith (1900–1901) and Ernst A. Bessey (1901–1903) were nominally in charge during the earliest years of the Section when Fairchild was abroad and officially listed as " plant explorer ".

Like Fairchild, his successors in charge of plant introduction in recent years have all had the requisite experience in agricultural exploration necessary for effective administration of this sort of activity. Generally speaking, plant introduction work in the second quarter of the present century has been much the same as it was in the first quarter, though certain of the objectives and methods have been changed. At least two innovations of this period deserve mention.

In 1927 a National Arboretum was established. Its preliminary development was administered by B. Y. Morrison, later head of the plant introduction work. Relationships between the plant introduction unit and the new arboretum thus became close, and because of this a valuable National Arboretum herbarium, originally specializing in economic plants, was built up cooperatively by these sister units. In 1949 the close-working association was broken by the appointment of separate heads for the Arboretum and for Plant Introduction, though cooperation in matters of the herbarium still is continued.

Of more import is the relatively new National Program cooperative between the States and the Federal Government, through which far more efficient testing and maintenance of plant introductions are effected. This program, discussed in more detail in later paragraphs, was started in 1947 and has developed largely through the initiative of the present head of the Plant Introduction Section.

THE SECTION OF PLANT INTRODUCTION AND ITS PRESENT ORGANIZATION

The present Section of Plant Introduction is conducted as one of several administrative units of the Horticultural Crops Research Branch, Agricultural Research Service, with headquarters at Plant Industry Station, Beltsville, Maryland. Fundamentally, the purposes of the Section are two: introduction into cultivation of new plant materials from all parts of the world; and preliminary testing of this material for potential use by agriculture in the United States. Such research as is conducted by the Section's personnel is related directly to one or the other of these basic purposes. A headquarters staff of plant introduction specialists administers the over-all program; planning explorations; arranging for exchanges or purchases of material from abroad; receiving; recording; and assigning new introductions to quarantine propagation when necessary, to trial or to experimentation.

An important present facet of the work of the Beltsville staff is to obtain plant materials in the United States needed by foreign research workers and to forward it to them for use in their investigations, thereby promoting an active international exchange of research stocks. The increase in United States Government Missions aiding in technical assistance programs abroad has amplified this procurement work tremendously, with the result that the Section now must be in a position to act as the clearing house for all requests for experimental lots of plant germplasm originating from foreign sources. Insofar as it is humanly possible, every effort is made to fulfill the

FIG. 3. Principal Administrators of U.S.D.A. Plant Introduction activity since its organization. Upper left: David Fairchild (1903–1928). Upper right: K. A. Ryerson (1928–1934). Lower left: B. Y. Morrison (1934–1949). Lower right: C. O. Erlanson (1949–).

requests of foreign research institutions. In this way friendly cooperation is fostered and mutual assistance rendered, making it far easier for the Section to conduct its own procurement programs abroad.

The Section of Plant Introduction also maintains agricultural explorers in the foreign field; a staff of botanists to aid in problems arising from plant introduction activity; an Inspection House in downtown Washington, D. C. (in cooperation with the Plant Quarantine Branch), through which all Departmental materials entering or leaving the country are funnelled; and isolated propagation facilities at Glenn Dale, Maryland, for introductions requiring quarantine. It also administers four Federal Plant Introduction Gardens, and has a cooperative part in the operations of five Regional and Inter-regional State-Federal Plant Introduction Stations at widely scattered locations to aid in the preliminary increase, testing, distribution and maintenance of plant introductions.

Plant Introduction

Plant Procurement and Exploration

The bulk of the plant material introduced from foreign and domestic sources is obtained through correspondence, exchange or purchase, or as gifts. A great part of it is obtained by deliberate intent, to be used in specific breeding programs or tested for use in the diversification of the agriculture of some region, but also some comes unsolicited from travelers, foreign service workers and friendly governments as international exchange.

Actual explorations are conducted when the plant materials needed cannot be obtained by other means, or when an intensive survey is necessary to obtain materials for important crop programs for specific regions. Through explorations come our most valuable introductions, the wild relatives of our cultivated crops, the very locally grown strains and varieties which may have genetic characters very useful to the breeder, and occasionally plants which may be the basis of completely new crops for the United States.

Ever since its inception exploration has been one of the most important activities of the Section. The list of plant hunters who have trod the obscure corners of the world in the search for valuable crop plants contains many names well-known to American agriculture. Professor Niels E. Hansen of the South Dakota College of Agriculture was the first individual to serve as agricultural explorer for the Section; his work is therefore of historical interest. In 1897 and 1898 Hansen undertook the first of several trips to Russia, Turkestan and Siberia. Travel at the time was arduous, and in one instance Hansen travelled overland 1300 miles by wagon, at another time 700 miles by sleigh. His introductions featured germplasm rich in cold-hardiness and drought-resistance. Hansen's introductions of fruits were particularly noteworthy as a source of breeding material; a germplasm collection of such items as apples, crabapples, pears and small fruits collected by him is still highly valued by horticulturists and is still being maintained at the Experiment Station at Brookings, South Dakota.

Practically concurrent with Hansen's earliest explorations were those of Mark A. Carleton in Russia for durum wheats, of Seaton A. Knapp in Japan for commercial rice varieties, of the general collecting of Walter T. Swingle in southern Europe and northern Africa, and of David Fairchild and Barbour Lathrop in South America. Space does not permit a discussion of the work of the many other individuals—including such well-known names as Frank N. Meyer, O. F. Cook, H. V. Harlan, Joseph F. Rock, Wilson Popenoe, P. H. Dorsett, W. J.

FIG. 4. Frank N. Meyer, dean of the Plant Introduction Section's agricultural explorers. From 1905 to 1918 he travelled many miles, many afoot, exploring eastern and northern China and Chinese Turkestan, bringing into America thousands of kinds of plants which have enriched its gardens, fields and landscape with the "plant gold" of the Orient.

Morse, Walter Koelz, Jack R. Harlan, Donovan S. Correll and Howard Scott Gentry—who have worked or who continue to work for the Department in the capacity of plant explorers.

The work of plant exploration may be carried out by regular scientists on the staff of the Section or by others—usually

The planning of explorations has always received much time and attention from a considerable number of scientific workers and cooperating agricultural agencies. The guiding principle behind each exploration is the need for and importance of a specific crop or group of crops. Pressing needs sometimes develop

FIG. 5. The Meyer Medal, established in 1930 with funds bequeathed the Plant Introduction Section by Frank N. Meyer and given periodically through the American Genetic Association to outstanding plant explorers. This, the first, was awarded to Barbour Lathrop. On the face of the medal is a Chinese inscription (in free translation meaning "In the glory of the thousand plants he takes delight"), flanked by two of Meyer's introductions, the Chinese White-barked pine (*Pinus bungeana*) and the Chinese date or jujube (*Zizyphus Jujuba*). The reverse is a pictorial representation of the first recorded expedition organized for collecting plants—that of Queen Hatshepsut of Egypt, who, about 1500 B.C., sent ships to the Land of Punt to obtain the Incense Tree.

Federal or State agricultural scientists—who are hired in a temporary capacity by the Section. Science has become so compartmentalized that it is obviously impossible to maintain a large staff of explorer specialists who can cover all the different fields of agriculture. In practice, therefore, the Section sends the best qualified men available for the specific problem in hand.

suddenly, as in the recent ravages of the virulent new strain of rust (15b) on the nation's chief wheat varieties. Breeders required all types of disease resistance as quickly as possible. Because of this need the Section immediately sent an explorer to Ethiopia, a known center of rust resistance and thus one of the most likely areas in which to find resistant stocks.

Most explorations do not develop on

such short notice but result in cooperative planning between workers at State and Federal Experiment Stations who bring together suggestions as to geographical areas to be explored and special crop groups to be collected, as well as to the order or priority in which explorations are to be made. The Section then undertakes the exploration work based on these recommendations, in both the foreign and domestic field. Because of varieties can be produced only if the right raw materials are at hand. The greatest natural resources of agricultural plant germplasm are in the centers of origin of our domesticated crops. For example, the countries mentioned above are rich in cereals, legumes, forage plants, vegetables and fruits. In mountainous areas of still primitive agriculture, hundreds of ancient crop types are yet to be found growing in geographical isolation.

FIG. 6. A plant explorer in the field. Wilson Popenoe, bringing out avocado budwood from the Guatemalan highlands, Baja Verapaz, Guatemala, 1917.

the importance of the Middle East and the area of adjacent southwestern Asia as an important center of origin of a host of our domesticated plants, this region has received much attention in recent years. Since 1948 plant hunters of the Section have traversed Turkey, Iran, Afghanistan, West Pakistan and India.

A primary reason why our plant breeders must obtain new stock from different parts of the world is that new No one can predict the value of such types in modern breeding programs, but we do know from past experience that it is just such seemingly useless plant introductions which have proved of outstanding merit in the improvement of our modern commercial crop plants.

To many of these backward countries, the borders of which encompass ancient centers of varietal wealth, have gone in recent years American or United Nations agricultural missions. Besides supplying

technological advice on agricultural problems, these groups, in order to improve the local economy, have been introducing standardized crop varieties as replacements for the primitive indigenous types. Thus our own technology is contributing to the loss of varietal wealth from the ancient reservoirs of crop germplasm. The urgency for sustained exploration is more than evident.

Besides agricultural exploration undertaken with regular appropriations of the Section, there may also be other explorations supported by special funds which become available from time to time. One example of such exploration is the search for possible plant sources of chemical precursors of the drug cortisone. The report on this extensive work has appeared in a previous issue of this journal (Vol. 9, No. 4). Another example is the collection of alkaloid-yielding plants throughout the world to be screened for chemical constituents useful in the treatment of heart diseases by the Laboratory of Chemistry of Natural Products of the National Heart Institute.

Inspection House

The Section of Plant Introduction has no regulatory functions nor does it issue permits for the entry of foreign plant material. Those functions pertain to the Plant Quarantine Branch, U. S. Department of Agriculture, Washington, D. C., which issues such permits as a part of its responsibility for guarding our borders against promiscuous entry of plant materials which may contain pests and diseases of potential harm to our agricultural crops.

Consequently, whatever its original source or manner of procurement by the Section, each plant immigrant passing through a port of entry first visits the U.S.D.A. Inspection House located at 224 12th Street, S.W., Washington, D. C. The Inspection House is operated cooperatively by the Plant Quarantine Branch and the Horticultural Crops Research Branch through the Plant Introduction Section. Because of this closely integrated operation the Section is the only agency permitted to bring into the country all categories of plant material, and even introduces cultures of disease-producing organisms for study by pathologists, but only under major regulations of the Secretary of Agriculture as administered and supervised by Quarantine officials.

At the Inspection House, Section personnel and inspectors of the Plant Quarantine Branch, working in close cooperation, open the packages containing plant introductions, give the individual collections in the shipment quarantine (P.Q.) and plant introduction (P.I.) numbers for the purpose of inventory, and inspect the material for diseases and pests. Depending on the kind of material and its condition on arrival, the inspectors may order it to be grown in quarantine, give it some fumigation treatment, or order it destroyed if too badly infected or infested. If quarantine is not necessary an order is made to the Inspection House by the Beltsville plant introduction staff to forward the material to the investigator or organization originally requesting its procurement or with which the Section may have cooperative arrangements for testing its value, as in the case of the Regional Plant Introduction Stations. If the introduction is of a kind that is of no immediate interest to any investigator or agency other than those on the Section staff it is ordered to one of the four Federal Plant Introduction Gardens for propagation and testing.

Inventory

Besides the plant introduction or accession (P.I.) number mentioned above, other data must be added to the Section's file of information which is brought together for each plant immigrant, whatever its source. The amount of data

FIG. 7. J. F. Rock in a plantation of young chaulmoogra trees (*Hydnocarpus*) established as a result of his explorations in Burma for the Plant Introduction unit, Hawaii, 1924.

available varies, but most explorers include the technical and vernacular names when known, exact locality data and pertinent descriptive, ecological or economic notes which may be of interest to those who may wish to utilize the plant introduction. Although there may be a delay of several years from the date of introduction, much of this information is eventually published in the permanent series of Plant Inventories which have been issued continuously since the formal establishment of a Federal unit for plant introduction in 1898. From these may also be gleaned the names of the explorers and the countries and dates of their field operations. Thus there is on permanent file in libraries throughout the country, as well as in leading agricultural libraries abroad, the only published historical record of all plant introductions (indexed by common and scientific names) made by the Department of Agriculture. Over 155 such inventories have been published to date, and upwards of 225,000 plant introductions have been accessioned. The earlier inventories often contained a mine of information on specific introductions, but for purposes of economy this useful practice has had to be discontinued.

In early years the inventory series also served in part as a list of foreign seeds and plants available for distribution and testing. Today the inventories are no longer current and serve solely as a chronological record of the plant introductions which have been accessioned at the Inspection House. The inventory is therefore not a list of plants available for general distribution; some introductions may be eventually destroyed as a quarantine precaution, others are requested for the sole use of specific individual workers, and many fail to grow. Introductions which do survive and become available for general distribution are listed much later on the temporary seed or plant lists issued by the nine introduction gardens and stations.

Botanical Investigations

Accurate descriptions and identifications of incoming material are essential parts of the necessary records kept in connection with introduced plants. At the Beltsville headquarters the Section has a staff of botanists for determining the correct classification of introduced plants or any other plants submitted for naming by the Department of Agriculture or cooperating institutions. These botanists investigate the areas of geographic origin of our cultivated plants to determine closely related species and varieties which may be of value in crop improvement programs; in addition, monographic treatments are prepared for economic plant groups in need of clarification, and floristic surveys of botanically little-known regions are made as required.

Among the well-known recent publications of the botanical staff are the "Manual of the Grasses of the United States" by A. S. Hitchcock, the "Geographical Guide to Floras of the World" by S. F. Blake and Alice C. Atwood, and the monograph on "Section Tuberarium of the Genus Solanum of North America and Central America" by Donovan S. Correll.

As an aid to the botanical investigator, the Section maintains a large seed collection, files of vernacular plant names used in different parts of the world, and cooperates with the National Arboretum in the maintenance of a reference herbarium of authentically named specimens.

Quarantine

Federal quarantine regulations, as stated in foregoing paragraphs, are administered by the Plant Quarantine Branch, Agricultural Research Service, Washington, D. C., from which may be obtained current information on the import control status of any plant material in which a research worker is interested. The most recent statement dealing with

FIG. 8. A plant explorer in the field. P. H. Dorsett securing scions of the Lantern persimmon north of Peiping, China, in 1931.

most quarantinable material is contained in Nursery Stock, Plant and Seed Quarantine No. 37, effective December 5, 1950. The various States have their own quarantines, which are independent of those described here.

In general, plant introductions subject to quarantine are those imported as vegetative propagations. Plants introduced as seed are seldom prohibited by quarantine procedures, but even here there are exceptions.

Quarantinable material is of two categories: (*a*) the class of plant material that may be introduced and grown under specified conditions of isolation and periodic inspection until certified as free of injurious insects and disease (post-entry quarantine); (*b*) that material entirely prohibited except when allowed to enter for research purposes by the U. S. Department of Agriculture.

Plants involved in post-entry quarantine may be sent directly to a State location, or in some instances the procedure may be modified to consist of one season's observation at the Plant Introduction Garden at Glenn Dale, Maryland, and another at the State location. The quarantine usually covers a period of two growing seasons but may be extended under some circumstances. A great deal of post-entry quarantine material is handled at Glenn Dale in an isolated nursery, where it can be kept under observation by inspectors of the Plant Quarantine Branch. This type of quarantine entails less work than other quarantine procedures.

Entry into the United States of clonal material of many species of plants is prohibited by law. Examples include grasses, citrus, grapes, white potatoes and sweet potatoes. Because it operates special quarantine greenhouse facilities, the Section of Plant Introduction is excepted from this restriction and can bring in restricted items for experimental and scientific purposes. For this reason the Section should be approached by workers desiring to bring in materials of a prohibited nature.

Plants to be quarantined are grown in specially constructed greenhouses and kept until fresh growth is secured for propagation, after which the original plant is destroyed. Quarantine procedures at their best are not perfect and are subject to revision as our knowledge of the insect and disease pests of plants increase. In recent years more and more information has accumulated on serious virus diseases whose detection under quarantine procedures is often difficult or impossible. Indexing techniques are now being resorted to during quarantine for plants subject to such diseases.

Propagation, Testing, and Distribution of Plant Introductions

Once a plant introduction has been received by the Section, inspected, declared free from pests and diseases, identified, numbered and recorded, it is ready for the next steps—increase propagation, testing and distribution. The original introduction, whether in the form of seed or clonal material, is usually limited in quantity and so has to be increased before it can receive wider distribution and testing. Preliminary testing and increase of stocks are usually done at field locations scattered throughout the country where a first idea is gained as to the potential usefulness of a plant immigrant to the agriculture of the United States.

As mentioned earlier, the Section of Plant Introduction operates four Federal plant introduction gardens and cooperates in the administration of five State-Federal regional plant introduction stations. Whether an introduction is ordered sent to one of the Federal or to one of the State-Federal locations, depends upon the nature and type of plant. The great bulk of plant introductions represent germplasm of established crops which is to be used in specific breeding

FIG. 9. A plant explorer in the field. W. H. Hodge, digging a Crinum bulb in Southern Rhodesia, 1951. The bulbs and corms of many genera of African Liliaceae, Iridaceae and Amaryllidaceae collected by the staff of the Plant Introduction Section have been tested as possible new sources of drugs.

programs. Much of this material falls in the category of field or vegetable crops and so is funnelled to the State-Federal cooperative stations. To the Federal plant introduction gardens go plants to be quarantined, woody species which cannot be handled as annual crops, certain types of ornamentals, and all little-known plants, concerning the potentialities of which as new crops not much is known. The only important exceptions are certain agronomic crops, including the small-grain cereals, cotton and sugarcane. Facilities and personnel are not available to the Section for the large-scale quarantine propagation required by these crops, and, since the work can be more satisfactorily carried out by specialists, all plant introductions of these are turned over to the investigators in the several crop units of the Department of Agriculture for growing under quarantine, for testing, and for distribution to the States.

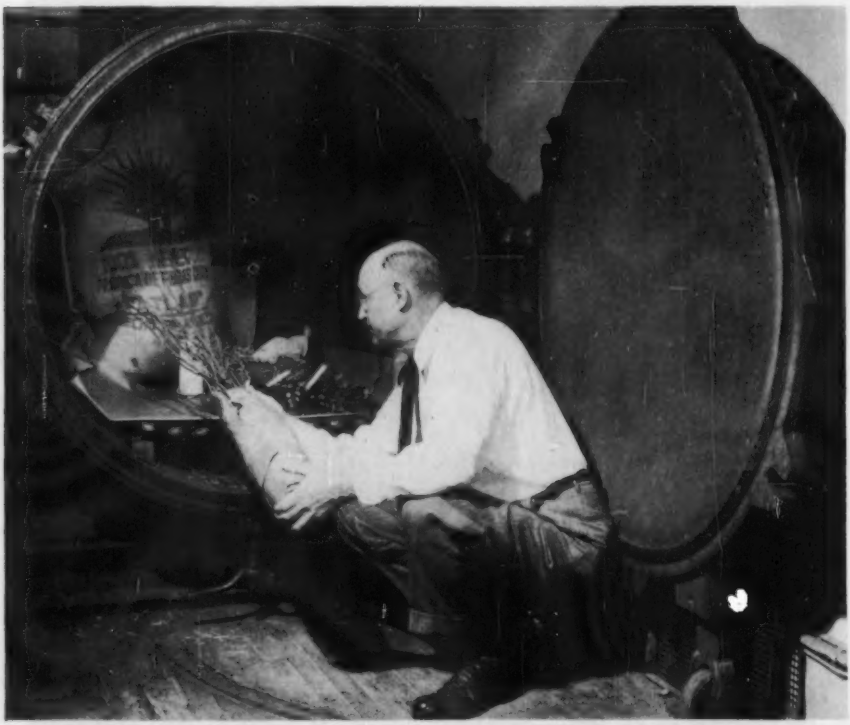


FIG. 10. Germplasm from around the world comes to us in the form of seeds and plants, cuttings and runners, bulbs and tubers. This material is inspected and fumigated (above) at the District of Columbia Plant Inspection House to make sure no insects or diseases are brought in. Samples then go to Federal and Regional Plant Introduction Stations for buildup and screening, often under quarantine.

Federal Plant Introduction Gardens

Gardens for testing new or little-known immigrant plants were recognized early by the United States Department of Agriculture as essential to the success of

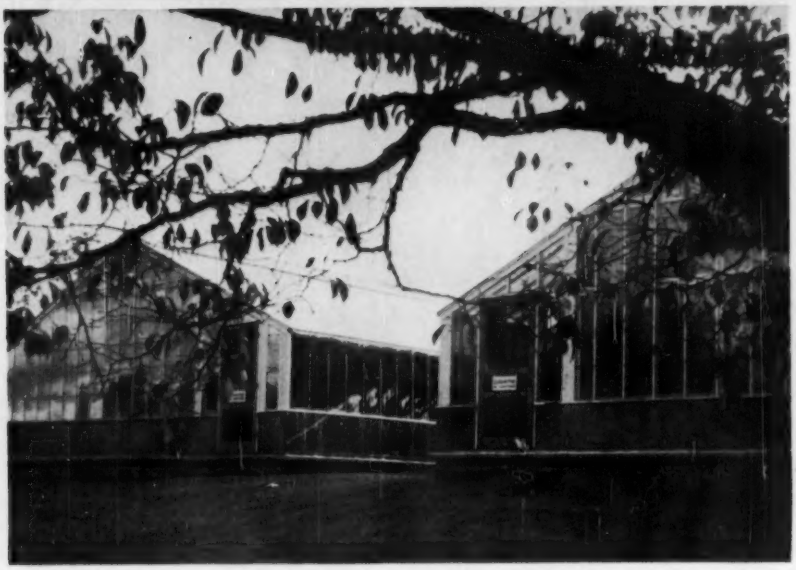


FIG. 11 (Upper). Donovan S. Correll, studying wild tuber-bearing species of *Solanum* growing at Sturgeon Bay, Wisconsin. Botanists of the Plant Introduction Section often have the advantage of being able to study living collections of economic plants, besides the usual herbarium material, for monographic purposes.

FIG. 12 (Lower). The center of quarantine activities for the U.S.D.A.—two of the specially constructed quarantine greenhouses at the Plant Introduction Garden, Glenn Dale, Maryland.

formalized plant introduction. Without ample growing facilities for handling plant introductions, all the effort and expense involved in obtaining plant germplasm abroad would be for nought. But in especially equipped gardens or nurseries, seeds, cuttings or plants may be increased, propagated and tested prior to distribution throughout the United States.

Thus it was that 1898, the same year that marked the formal birth of a regular Federal program for plant introduction, saw also the establishment of the first federal Plant Introduction Garden. This was a modest 6-acre tract, located on Brickell Avenue close to what is now down-town Miami, Florida, but since returned to the original owners, and the plants transferred to the present Garden near Coconut Grove. In 1904, enthusiastic citizens of Chico, California, became so interested in having their town chosen as a second site for a similar introduction garden that they purchased 80 acres of land and turned it over to the Federal Government for this purpose. An urgent need for a location near operational headquarters at Washington, D. C., finally resulted in the establishment in 1919 of the Garden at nearby Glenn Dale, Maryland, where immediate care could be given to plant material weakened by long delays in transit from abroad and for purposes of quarantine isolation when necessary. The last of the four Federal locations, the Barbour Lathrop Plant Introduction Garden, Savannah, Georgia, was also established in 1919 as a gift of its namesake who hoped to preserve for posterity a grove of the giant timber bamboo that had been established on the property.

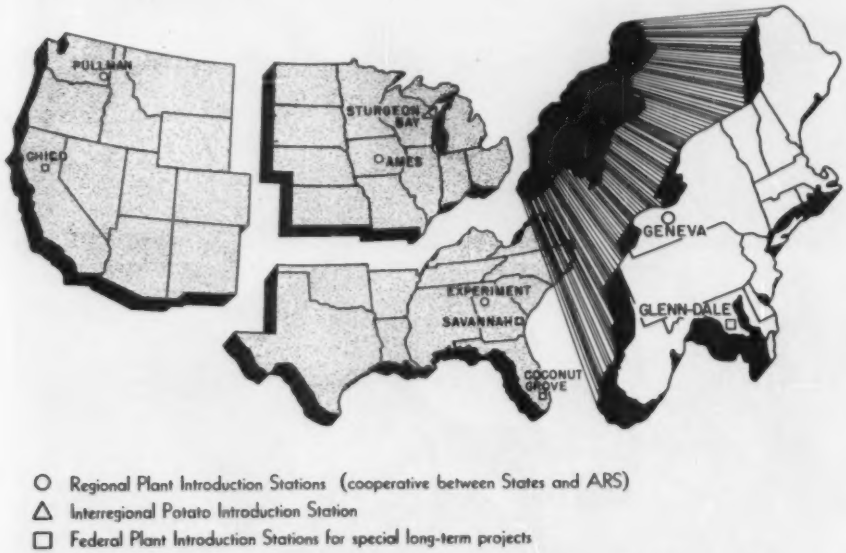


FIG. 13. The primary locations handling plant introductions in the United States.

Although the four plant introduction gardens just mentioned constitute the only strictly Federal locations currently operated by the Plant Introduction Section, other gardens have existed in the past. Thus from 1919 to 1925 a test

FIG. 14. (Upper). Federal Plant Introduction Gardens—Mexican *Cnidosculus* trees, in winter condition, at the Plant Introduction Garden, Coconut Grove, Florida. This genus of trees is a latex-yielder and is an example of the numerous tropical or subtropical latex species maintained at that Garden.

FIG. 15 (Lower). Federal Plant Introduction Gardens—Experimental orchard of pistachio trees at the Plant Introduction Garden, Chico, California. Most tree crops, especially when little-known, require a long period of testing. After a quarter century of work, the pistachio is only now reaching the point where selections can be released to growers.

FIG. 16 (Upper). Federal Plant Introduction Gardens—*Rauvolfia serpentina*, a recent drug plant introduction from India, undergoing propagation increase in the greenhouses at the Plant Introduction Garden, Glenn Dale, Maryland, prior to field testing elsewhere.

FIG. 17 (Lower). Federal Plant Introduction Gardens—Entrance to the Barbour Lathrop Plant Introduction Garden near Savannah, Georgia. The entrance gate with bamboo veneer and the little bamboo museum building (shown) indicate the chief activity of this Garden.

garden was maintained at Brooksville, Florida, but its work was later transferred to the Savannah Garden. Similarly a garden leased at " Yarrow " near Rockville, Maryland, served the Washington, D. C., area from 1910 to 1919, when the present permanent Garden at Glenn Dale, Maryland, was set up.

Among other test gardens, now defunct, were those once operated at Brownsville, Texas, and Bellingham, Washington. The latter location was especially selected for the increase of bulbous species. These locations were active at a time when tens of thousands of seeds had to be produced annually for the Congressional Seed Distribution. This costly and highly ineffectual method of disseminating and evaluating plants ceased in 1925, and the years since have seen the practical termination of the program of indiscriminate distribution of free plants to hosts of private experimenters, mostly amateurs, unqualified for this type of work. Today the plant materials held at the Plant Introduction Gardens are not available to the general public but are destined for testing primarily by qualified researchers in the Department of Agriculture or their counterparts at State Experiment Stations or other bona fide agricultural institutions either here or abroad.

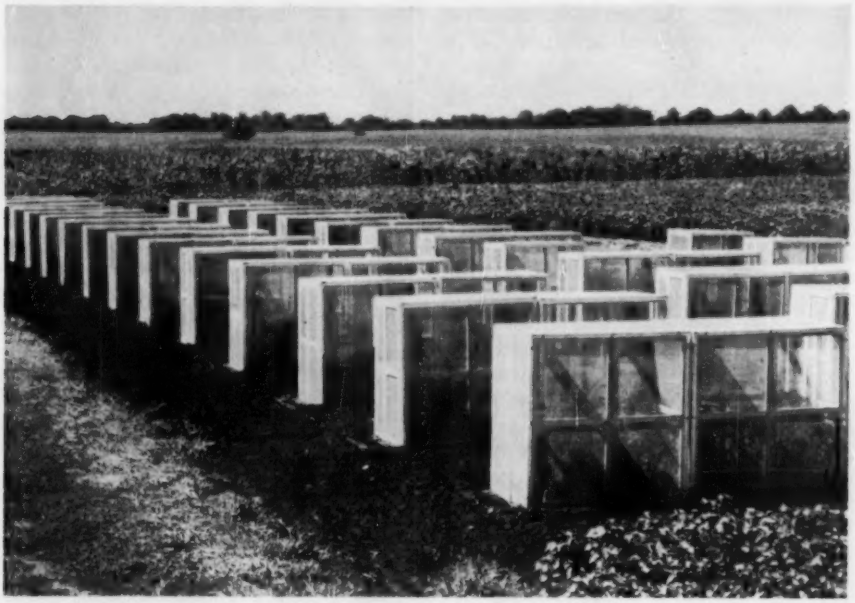


FIG. 18. State-Federal Plant Introduction Stations—Isolation cages for plant introductions at the Regional Plant Introduction Station, Ames, Iowa.

People are often initially confused as to the exact functions of the Plant Introduction Gardens. They are neither botanic gardens nor arboreta in the true sense of these words nor are they true Experiment Stations. Yet some of the work of each of these types of organizations is shared by these Gardens. Plant Introduction Gardens are like botanic gardens in being, among other things, repositories of living plants; but unlike collections in botanic gardens those in an

Introduction Garden are limited to plants with present or potential economic value to man.

Introduction Gardens often lack the well-groomed look and landscaping characteristic of botanic gardens and arboreta. For purposes of ready reference and economy of maintenance it is easier to set out immigrant plants in simple blocks or rows. And for purposes of preliminary evaluation, once placed in the field, the plants must shift for themselves without undue special attention. The Plant Introduction Garden collections often have a quicker turnover in plants. Valuable species, once widely established, usually no longer need to be held. Likewise material once proved of no value is discarded.

Because of the necessity for propagating rapidly a wide series of plant material, the growth requirements and life history of which little is often known, the Section undertakes research on propagation methods at its Federal Introduction Gardens. The adaptability of various types of media for the germination of seed, the use of various wave lengths of light for seedlings and for the rooting of cuttings, and the efficacy of growth regulators and various techniques for the growing of plants are or have been investigated. Since the Introduction Gardens have handled thousands of shipments of living plants, they have also utilized special techniques, such as the use of polyethylene wrapping and sphagnum rooting media, to insure that plants arrive safely at their ultimate destinations.

Some types of plants sent to the Introduction Gardens receive much more exhaustive tests than others. These have to do with material with which the Section hopes to establish entirely new crops for the United States, or, if the material is not new, to establish a new method of utilization for an existing crop. Often the bringing together of species and varieties for the study of their taxonomy and life histories, growth habits, adaptability and economic utilization, requires investigations running into many years before selective introductions can be recommended to growers. Examples of now well-established specialty plants which have " graduated " from the Section's program include the Glenn Dale hybrid azaleas, avocado, date palm, tung tree and Oriental chestnut; while among plants still " matriculating " can be mentioned timber bamboos, pistachio nut, reserpine-yielding *Rauvolfia*, and tropical drug-producing yams. The better known plant introductions enter directly into use in American agriculture; many others, often unimportant or even undesirable as regards their horticultural characteristics but carrying much needed resistance to disease, play obscure though highly valued roles known only to plant breeders.

In the course of making exhaustive tests on certain categories of material, large collections are built up and held for long periods. Although these collections change during the course of years, at any one time each of the Federal Plant Introduction Gardens may have several thousand introductions being held in various stages of test. The Gardens therefore constitute important reservoirs for plant germplasm.

The Coconut Grove, Florida, Plant Introduction Garden. Although Miami can boast of having the first Federal plant introduction garden, the present one, some 13 miles south of Miami near Coconut Grove, is actually the third introduction garden in the general area. The little original Brickell Avenue plot soon outgrew its bounds and was supplanted by a tract at Buena Vista, north of Miami. The present garden near Coconut Grove occupies what was in World War I an Army aviation base, Chapman Field, turned over to the Department of Agriculture in 1923. The

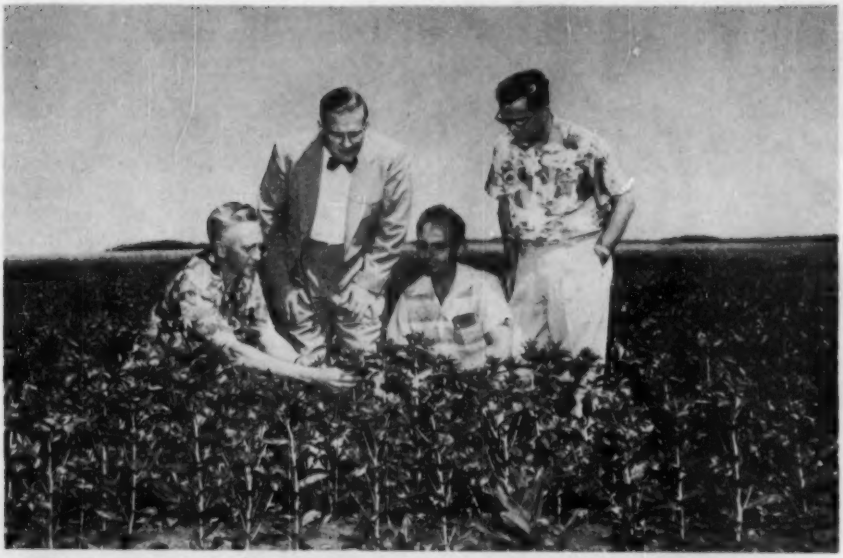


FIG. 19 (Upper). State-Federal Plant Introduction Stations—Lowell A. Mullen (left) of the Regional Plant Introduction Station for the Western Region at Pullman, Washington, showing new safflower introductions to interested visitors.

FIG. 20 (Lower). State-Federal Plant Introduction Stations—Part of the plantings of recently introduced legumes at the Regional Plant Introduction Station, Experiment, Georgia. Each accession is grown in a rod row for purposes of seed increase, observation and preliminary evaluation.

FIG. 21. State-Federal Plant Introduction Stations—The snake melon (*Cucumis melo* var. *flexuosus*) from Afghanistan, an unusual plant immigrant, growing at the Regional Plant Introduction Station, Geneva, New York.

Garden has expanded since that date and now occupies some 197 acres, a third of which is still undeveloped. Here is a relatively frost-free testing ground for many tropical and subtropical introductions of interest to workers in peninsular Florida, the warmer parts of the Gulf Coast, southern California, Puerto Rico, the Virgin Islands and Hawaii.

Situated on rocky limestone soils, Coconut Grove is not fitted for testing agronomic crops and so is almost exclusively used for woody species. About 3,000 introductions, many represented by numerous specimens and including about 200 species of palms, various insecticide plants, miscellaneous latex-producing species, mangoes, lychees and papayas as well as many lesser-known subtropical fruits, are held under observation and test.

Certain plants grown at Coconut Grove are of no importance to the U.S. farmer as domestic crops but are of extreme interest to all our citizens who are the greatest consumers of the products of these plants. They include highly-strategic natural rubber (*Hevea*) and coffee, which are represented by germplasm collections of important strains. From the Garden's collection of some 250 clones of *Hevea brasiliensis* have come budstocks of disease-free or high-yielding rubber trees now found in young plantations throughout the American tropics. The collection of world coffee species and varieties, maintained in this disease-free area, insures this hemisphere's coffee-producing countries of important breeding lines, should serious Old World coffee diseases that threaten gain entrance to tropical America.

Coconut Grove is especially rich in woody ornamentals, and the value of this introduction garden to subtropical horticulture in our country is immediately apparent to the visitor to southern Florida where the great majority of ornamental plants grown, whether as street trees or garden subjects, can trace their parentage to immigrants originally tested here by the Section.

The Chico, California, Plant Introduction Garden. At Chico, in the Sacramento Valley of northern California, is located a second Plant Introduction Garden of 210 acres in the center of one of the nation's leading drupaceous fruit and nut areas. Although formerly considerable emphasis was placed on ornamentals, the Chico Garden has always been and still is today primarily a center for the evaluation and increase of stone-fruit and nut species.

In the present germplasm collection at Chico are 1100 clones and varieties (as well as 3000 stone fruit seedlings), comprising 250 cherries, 195 apricots, 450 peaches, 70 nectarines and 200 plums. In addition, there are 250 to 300 miscellaneous woody (deciduous and evergreen) ornamental and specialty crop

FIG. 22. State-Federal Plant Introduction Stations—Collecting material for chromosome studies from wild potato introductions growing at the Interregional Potato Introduction Station at Sturgeon Bay, Wisconsin. Much basic information on the crossability of tuber-bearing species is obtained through the cooperation of graduate students of the University of Wisconsin.

accessions; seven named pistachio (*Pistacia vera* L.) varieties plus 750 seedlings and nine species of *Pistacia;* 200 English or Persian walnut seedlings; Oriental chestnuts; as well as miscellaneous fruits such as the Chinese gooseberry (*Actinidia chinensis* Planch.), Chinese date or jujube (*Zizyphus jujuba* Mill.), few introductions may measure up to varieties grown in the United States, there are always outstanding characters of interest to the fruit breeder who may utilize them in the development of still better commercial varieties.

The Glenn Dale, Maryland, Plant Introduction Garden. The Glenn Dale

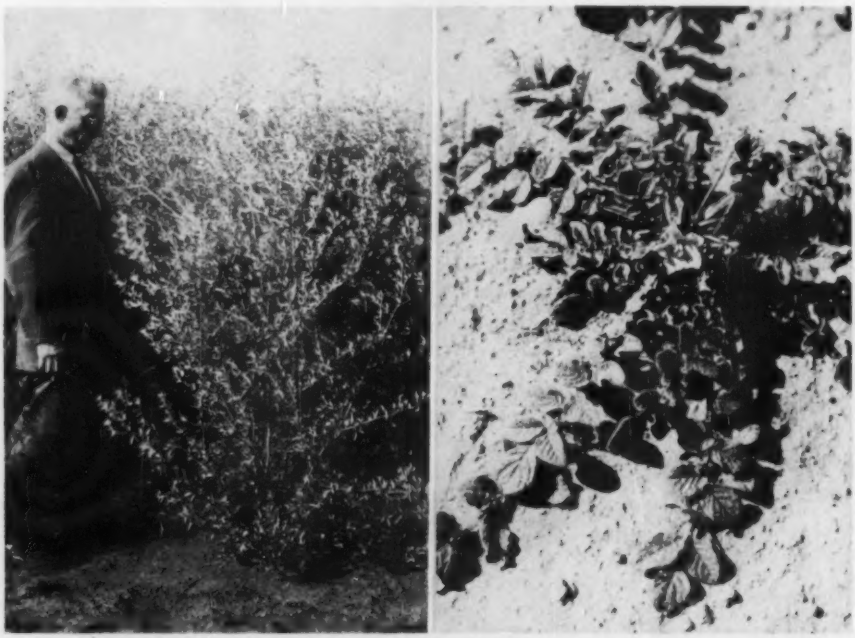


FIG. 23 (Left). Recent promising plant introductions—a sweetclover (P.I. 200355) from Israel, growing at the Regional Plant Introduction Station at Ames, Iowa. The outstanding vigor and lateness of maturity of this immigrant make it of potential use in breeding programs.

FIG. 24 (Right). Recent promising plant introductions—*Solanum acaule,* a wild tuber-bearing potato from the Andes, selections of which are notable for their immunity from X-virus and ability to withstand temperatures down to 23° F., hence of much interest to potato breeders. Potato Introduction Station, Sturgeon Bay, Wisconsin.

olive, pear, Oriental persimmon and pomegranate.

Evaluation of any fruit or nut, about which little is known, consists of year by year recording of tree characters such as time of bloom, foliation, bloom hardiness, disease and insect resistance, yield; and such fruit characters as size, color quality, and maturity. Though only a station is the most highly developed of the four Federally operated gardens, serving as it does the nearby Inspection House in Washington and acting as the important center of all special quarantine activities undertaken by the Section, with the exception of quarantine of *Hevea* rubber plants. Although the garden totals only 70 acres, nearly all of

which is under cultivation, it maintains some 6,000 introductions under observation or test, or in process of propagation for distribution. The most important series of introductions now undergoing preliminary evaluation belong to the deciduous fruit category, with ornamentals next in importance. Ample greenhouse units and fine facilities for propagation of all types of plants have meant that the Glenn Dale Introduction Garden has been the one generally used for extensive jobs of propagation, not only of specialty items for the United States but also for foreign-aid programs of the government as well.

During World War II some four million seedling cinchona trees (quinine) were grown at Glenn Dale and distributed to Latin America. Recently large series of coffees, the important spice, black pepper (*Piper nigrum* L.), as well as potentially valuable drug species of *Dioscorea* are or have been extensively propagated. In 1952 a small seed storage unit was completed. In the special environment of its storage chambers, held at 33° F. and 30% relative humidity, are being held a host of introductions in the form of seed, the vitality of which, if held under normal storage, would soon be lost.

The Barbour Lathrop Plant Introduction Garden, Savannah, Georgia. Located some 12 miles south of Savannah is the smallest (50 acres) of the Federal introduction gardens. Here is held a miscellany of ornamentals as well as plants of a so-called specialty-crop nature. Among the most important are outstanding hollies, edible aroids (*Colocasia* spp.), drug-yielding dioscoreas, blight-resistant Oriental chestnuts (*Castanea* spp.) and the quite-distinct Chinese water-chestnut, or *matai* (*Eleocharis dulcis* (Burm. f.) Trin.).

Above all this garden is noted for its germplasm collection of hardy Oriental bamboos, especially of the genus *Phyllostachys*, suitable to warm temperate areas in the United States. Utilitarian bamboos of the type to be seen at Savannah have been grown and used extensively for centuries by the peoples of China and Japan. It is believed that eventually many home and farm uses will be found for bamboos grown on southern farms. Perhaps the greatest potential of bamboo lies in industry, where it may serve among other things as an important new source of paper pulp. To investigate some of the industrial possibilities, the Section has supported several lines of research on bamboo under contract, utilizing the plantings at Savannah as sources of test materials.

State-Federal Cooperative Plant Introduction Stations

It was mentioned earlier that, since the great bulk of plant introductions handled by the Section involves germplasm (usually in seed form) of well-known crop plants, this material is turned over to State-Federal cooperative stations rather than to the Federal plant introduction gardens which lack facilities and personnel to handle such work. Prior to 1946 most introductions of this type were farmed out to various crop experts in the Department, but for one reason or another this method of handling introductions was never completely satisfactory.

Under the Research and Marketing Act of 1946, funds became available for the first time to establish a formal National Cooperative Program for the introduction and testing of plant material for crop and industrial uses and for the preservation of valuable genetic stocks. In this cooperative effort the Plant Introduction Section is held responsible for all exploration and introduction, while to the States and other cooperating agencies falls the job of evaluating all introductions that are made in this program.

Thus an opportunity is afforded to coordinate the introduction and evaluation of new plant material on a much broader and more thorough basis than has been possible before—broader because every State as well as Puerto Rico, Hawaii and Alaska through its own Experiment Station can enter into the test program; and more thorough because of reporting procedures required as a prerequisite to receiving introductions for test. As a result of this Act both the Section of Plant Introduction and the States receive funds annually, in one case to conduct plant exploration and in the other to coordinate the testing of plant introductions throughout the nation.

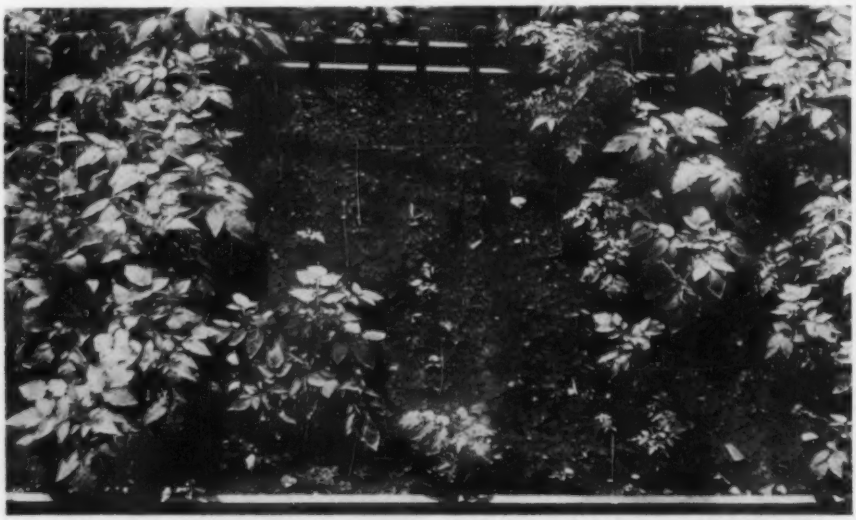


FIG. 25. Recent promising plant introductions—Tomato introductions from the Ames, Iowa, Regional Plant Introduction Station undergoing cooperative screening for diseases at the Ohio Agricultural Station at Wooster. Certain of the introductions are proving susceptible (center), while others are showing resistance, a character which breeders can transfer to commercial tomato types.

For operational convenience in coordinating the National Cooperative Program, the United States has been divided into four regions, Northeastern, Southern, North-Central and Western, each with a Regional Project (NE-9, S-9, NC-7, and W-6). The manner in which the cooperation develops in each of the four regions for this national program is decided by the States themselves through their Agricultural Experiment Stations in consultation with the Agricultural Research Service of the United States Department of Agriculture as represented by the Plant Introduction Section.

In each region there has been established a Regional Plant Introduction Station with a Coordinator in charge to supervise its activities. These stations are located at Geneva, New York; Experiment, Georgia; Ames, Iowa; and Pullman, Washington—in each case being placed at one of the principal State Experiment Station locations, where are to be found the physical facilities necessary for conducting regional operations.

Plant immigrants to be tested under this program are ordered by headquarters personnel of the Plant Introduction

FIG. 26 (Upper). An outstanding plant introduction—the soybean, which prior to the activities of the Plant Introduction Section, was almost unknown in the United States. American farmers at present grow over 16,000,000 acres of soybeans, yielding an annual farm income of nearly a billion dollars.

FIG. 27 (Lower). An outstanding plant introduction—the date palm. Exploration for the best date varieties of the Old World was an early activity of the Plant Introduction Section. California date groves, like the one shown, now supply the United States with about one-half of her date requirements and bring to the American date farmer over $2,000,000 a year.

Section directly from the Inspection House to the coordinator at one or more of the cooperative regional stations. Because of their geographical location, certain regions obviously are better fitted than others to handle at least the preliminary increase and testing of specific crop items. Of course all introductions are eventually available to all States interested, with the result that there is a free inter-exchange of materials between regions through the coordinators.

The white potato is tested cooperatively under the National program through a special Inter-Regional Project (IR-1) which maintains an important germplasm collection of tuber-bearing species of *Solanum* at the Wisconsin Peninsular Branch Experiment Station at Sturgeon Bay.

Whenever possible, plant introduction material submitted by the Section to the regional or inter-regional stations is given sufficient preliminary evaluation so that interested States may be in a position to determine whether such materials may have potential value in their research programs. The accessions are also multiplied so as to permit as wide distribution of seed or plant lots as may be required. At the end of each year detailed seed or plant lists are brought together at each location for distribution to all State Experiment Stations. Such lists indicate plant introductions currently available through the National Cooperative Program.

With the gradual accumulation of plant introduction materials, each Regional Station is becoming more and more like a bank for holding valuable plant germplasm. Most of this material, largely annual crops, can be held in ordinary seed storage. That which is in regular demand, like a checking account, goes into the Regional Station's own storage room. That which is potentially, but not immediately, important, like a savings account, may be temporarily stored in the rather limited facilities operated by the Plant Introduction Section at its Glenn Dale Plant Introduction Garden.

The National Cooperative Program has now been in active operation since 1948. About a dozen explorations, all specifically requested by the cooperating States, have been made under its auspices.

BENEFITS RESULTING FROM FOREIGN PLANT INTRODUCTION

Space does not permit the lengthy statement that would be required to mention the more valuable plant immigrants that have become established in the United States through the activities of the Plant Introduction Section. The majority of those mentioned were introduced more than a score of years ago. Plant immigrants resulting from recent explorations have yet to prove themselves, evaluation often requiring a decade or more. What follows is a digest of some of the more valuable introductions made by the Department. These are the ones that have, in some cases, revolutionized the agriculture of large areas of the United States; many others of equal importance have played obscure genetic roles—impossible to describe here—known only to plant breeders.

Among cereals, the hard red winter wheats—so important in bread-making—with some 27,000,000 acres grown annually in this country, have all been derived from plant introductions. The varieties Kharkof, Kubanka, Baart, Federation, Pentad, White Federation, Onas, Galgalos, Hard Federation and Kahla—all introduced by the Department—are among leading varieties planted in the important wheat-growing regions. Among barleys, Trebi from Turkey and Club Mariout from Egypt are widely grown in the West where rainfall is low. Our rice industry consists almost wholely of varieties developed from plant introductions, among the first of which were

those collected by S. A. Knapp in Japan; rice is grown on approximately a million acres and represents an annual value of $30,000,000.

Like cereals, forage crops have been introduced by the Section in large numbers. The high continuing demand for legumes and grasses is indicated by the other now-familiar grasses were once introductions; they include Centipede (*Eremochloa ophiuroides* (Munro) Hack.), Dallis (*Paspalum dilatatum* Poir.), Bahia (*Paspalum notatum* Flügge), Napier (*Pennisetum purpureum* Schumach.) and Rhodes (*Chloris gayana* Kunth) grasses. Their importance even extends to our

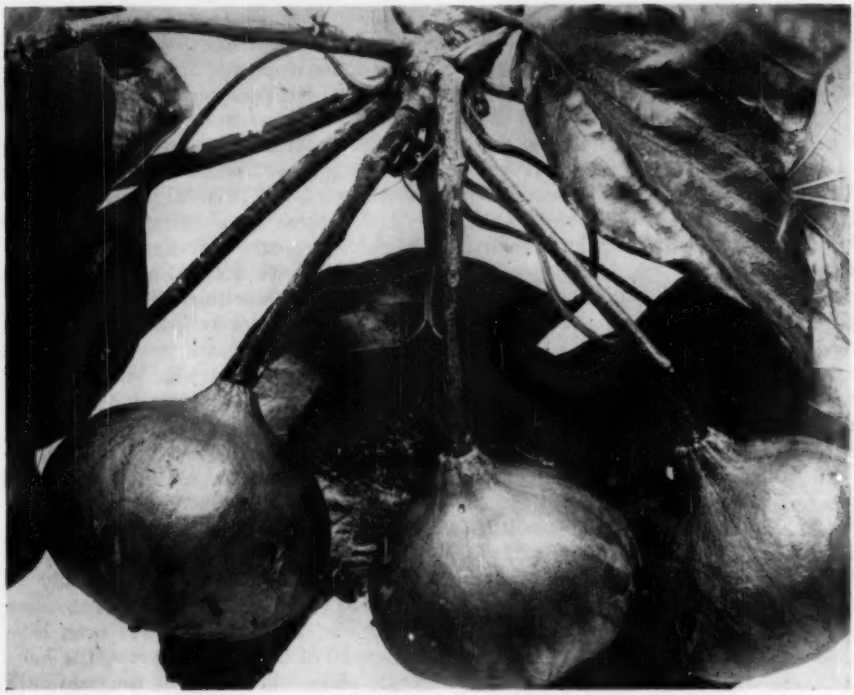


FIG. 28. An outstanding plant introduction—*Aleurites fordii*, whose nuts are the source of tung oil. In 1953 the Gulf States produced 120,000 tons of nuts, representing a total farm income of $8,000,000.

fact that the most recent explorations undertaken have had as their primary purpose the collection of forage materials. Outstanding among forage grasses is crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.), today boasting an annual farm value of $4,000,000. There have been a number of introductions of this species, but the first was obtained in Siberia by Niels Hansen in 1898. Many lawns with the familiar common Bermuda (*Cynodon dactylon* (L.) Pers.) as well as those newer luminaries, Frank Meyer's Zoysia (*Zoysia japonica* Steud.) and African Bermuda grasses (*Cynodon transvaalensis* Burtt Davy and *C. magennisii* Hurcombe).

Twenty-five years ago the progenitors of the soybean types (*Glycine max* (L.) Merr.) now grown in our country were

collected in Asia by P. H. Dorsett and W. J. Morse. Their two-year trip cost American taxpayers about $50,000. The new industry they helped to found in this country is now worth more than a billion dollars a year. Taxes paid by producers of this crop alone have repaid many times the total cost of all plant introduction work since its formal inception in 1898.

But soybeans are not the whole story. There are the alfalfas (*Medicago sativa* L.)—including Ladak from India, Hairy Peruvian from South America and Creeping alfalfa from Turkey; all the clovers —some dozen or more; Kudzu (*Pueraria lobata* (Willd.) Ohwi); cowpeas (*Vigna sinensis* (L.) Savi); velvet beans (*Stizolobium deeringianum* Bort.); crotalarias; vetches (*Vicia* spp.); and lespedeza. All our Korean lespedeza (*Lespedeza stipulacea* Maxim.) came from a handful of seed collected for the U.S.D.A. in 1919 by Ralph Mills, a medical missionary; that handful of seed from Korea has mushroomed into a $120,000,000 a year crop.

In cotton the most outstanding find of plant exploration was Acala, the germplasm of which has contributed to a series of superior, drought-resistant, bigboll cottons with an excellent quality staple. Found in 1906 by G. N. Collins and C. B. Doyle as a dooryard plant in a Mexican hamlet from which it derives its name, Acala cotton, in one or more of its selections, has subsequently become the most important cotton in the American Southwest. California growers alone pocket millions of dollars annually from this fabulous plant.

Horticulturists have long recognized the value of plant introductions and down through the years have been supplied with a rich heritage of plant germplasm from abroad. Scores of varieties of beans, cabbage, carrots, lettuce, onions, peas, peppers, pumpkins and squashes, radishes, maize and the like represent either direct plant introductions or first-generation selections. In these days of constant warfare against disease, present-day vegetable breeders are looking more and more to related wild species for use as parental material in vegetable improvement programs.

The white potato, wholely American in origin, is in itself a good example. Since 1932, 56 new potato varieties have been released in this country by breeders and all but one can boast of foreign introductions in their pedigrees. What is more, selections of the wild potato species obtained in Mexico and South America by such men as Donald Reddick, C. O. Erlanson, H. G. MacMillan and Donovan S. Correll are showing up as sources of valuable genes. For example, *Solanum acaule* Bitt. selections, immune from X virus, also can withstand temperatures down to 23° F.; *S. antipoviczii* Buk. and *S. chacoense* Bitt. are immune from Y virus; and many introductions of *S. demissum* Lindl. carry late-blight resistance. The same thing can be said of the tomato whose wild cousin, collected in Peru by H. L. Blood and L. Tremelling, has supplied resistant factors for such serious troubles as Fusarium wilt and root-knot nematode.

Results do not appear so quickly in the field of tree crops because of the slow growth of such plants. Yet even here examples of the contribution of the Federal plant introduction program are legion. Mention must be made of the avocado, whose introduction is properly associated with the explorations of Wilson Popenoe; the date, which owes its establishment to the fieldwork of W. T. Swingle, Silas Mason and T. H. Kearney; the lychee, also backed by the efforts of Swingle in cooperation with Weidmann Groff; the Chinese tung tree, one of David Fairchild's special pets; the Shalil and Yunnan peaches, collected in Asia by Joseph Rock; the jujube and certain of the Oriental persimmons, first trans-

planted to America by Frank Meyer; Chinese chestnuts, also first introduced by Frank Meyer, but whose outstanding disease resistance made them particularly sought out in large numbers by P. H. Dorsett, P. Kent Beattie and Peter Liu; and such other items as the Geneva apricot and Quetta nectarine which owe their success as outstanding seedlings selected at the Plant Introduction Garden at Chico by the keen eyes of one of the many men who back up the work of plant explorers by seeing that introductions are safely established.

Largely because of the lack of proper organization of the varied groups interested in their promotion, ornamental plants have always been greatly overshadowed in the program of Federal plant introduction by their agriculturally important cousins. The production of ornamental materials in the United States is big business. Take, for example, the cut orchid flower business whose annual retail value approximates $25,000,000, or the 1953 value of lawn grass acreage which in Los Angeles County alone was $262,000,000. It can be seen from this that sooner or later Federally-supported exploration for ornamentals will be made.

Woody ornamentals require long-term evaluation, as demonstrated by the fact that only in 1953 could a report be issued by the U.S.D.A. recommending for the northern Great Plains a series of several dozen hardy trees and shrubs collected some 40 years earlier by our explorers in northern China and Japan. That ornamentals have not entirely been overlooked (plant explorers often pick them up as a side-line on otherwise strictly agricultural explorations) has already been shown in the galaxy of showy tropical and subtropical woody plants—many collected by Fairchild—which have emanated from the Plant Introduction Garden at Coconut Grove to enrich the gardens of Florida and California. There are others, too: Washington's famed Japanese cherries; the hardy, rapid-growing Chinese elm (*Ulmus pumila* L.), found by Frank Meyer in Chihli province; *Rosa xanthina*, a hardy yellow rose also sent in by Meyer; the Chinese holly (*Ilex cornuta* Lindl.) and a striking compact form of it recently discovered on the Gulf coast. Most recent contribution by the Section in the field of ornamentals is the striking series of Glenn Dale hybrid azaleas, the result of a breeding program conducted by B. Y. Morrison, in which he incorporated the genes of a number of azalea introductions.

The illustrations given represent but a few of the host of successful introductions that have been made since 1898 when the Plant Introduction Section of the Department of Agriculture was formally organized. They indicate how indispensable is sustained plant introduction work to the dynamic agricultural economy of our nation.

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Utilization Abstract

Seaweed Colloids. Seven colloidal extracts are obtainable from seaweeds—agar, algin, carrageenin, agaroid, fucoidin, iridophycin, laminarin—but only three of them, first mentioned here, have any commercial value. The industry that produces them in the United States has had phenomenal growth in the past decade; from 1945 to 1955 the value of these three colloidal products rose from $2,000,000 to over $10,250,000, and by 1975 gross sales are expected to be near $20,000,000. Demand for the commodities has increased so much that the major problems facing the industry do not concern outlets but mechanized harvesting of the plants and accurate data on the quantities and locations of seaweed beds.

Ninety-five percent of the dollar value of these products, marketed under a variety of names, is accounted for by the five big concerns—Kelco Co., Algin Corporation of America, Seaplant Chemical Corporation, Kraft Foods Co. and American Agar and Chemical Co. Most of the remaining five percent comes from five other companies—Bowey's, Inc., Chocolate Products Co., Robert A. Johnston Co., Stein-Hall, Inc. and Jacques Wolf and Co. In addition to the foregoing ten, there are minor processors.

The great increase in this plant-utilizing industry, little heard of 20 years ago, was occasioned by the war-born need to replace the seaweed extracts formerly imported from Japan, Ireland, Scotland and France. (B. Idson, *Chemical Week, July 21, 1956*).

Bamboo in the Economy of Oriental Peoples

As ornamental subjects and as the source of raw material for papermaking, textiles, basketry, matting, rope, house construction, furniture, bridges and fishing equipment, bamboos have a greater diversity of uses in the Orient than any other group of closely related plants.

F. A. McCLURE [1]

Bamboo is fascinating alike to the artist, the poet, the craftsman and the scientist. The Western traveler in the Far East has never failed to be intrigued by the ubiquity of bamboo and by the number of ways in which it enters into diverse phases of the life of the people. He has been struck by its beauty as an ornamental and by its astonishingly varied role in the arts and industries. He has listed its multitudinous uses, praised its virtues and advocated its incorporation into Western agricultural and industrial economy.

Bamboo as a Garden Ornamental

Bamboo is an essential feature of many planned landscapes in the Orient: the elaborate and extensive gardens characteristic of the Golden Era of China, the more restricted type peculiar to Japan today, the relatively tiny secluded inner court of inn, tea-house or private dwelling where there may be room for little more than a bamboo screen (Fig. 1). In Oriental gardens we find living bamboos used as hedges, borders and screens, in mass plantings, in groves and in isolated clumps. Dwarf forms are often used, in Japan at least, as ground cover for open park-like areas, and especially under pine trees.

Some bamboos are suited to a great variety of treatment, while others are less responsive to the skill of the gardener. The most tractable are the ones commonly employed in pot culture. Several types of manipulation are practiced to produce either dwarfed specimens or bizarre topiary effects. The dwarf habit is sought especially in connection with the production of miniature gardens, though many dwarfed specimens are cultivated individually in pots or trays solely for exhibition.

Dwarfness may be a natural state related to genic constitution, or it may be the result of cultural treatments involving controlled watering and restricted nutrition. Certain devices are employed for simulating the dwarf habit by more direct methods to avoid spending the time required for bona-fide dwarfing. Sometimes a bamboo culm of large dimensions is separated from its mother clump, cut down to a short stump, and transferred to a suitable pot just before new growth starts. The ensuing growth is greatly reduced from the normal size, and the presence of the stump itself is considered, by a certain school of gardeners and plant fanciers, to enhance the artistic merit of the general effect. This treatment is usually practiced with bamboos of the clump type of growth, where the new shoots originate from the base of the mother culm.

Another method is used with bamboos of the running type, in which the new culms normally arise from lateral buds of the slender horizontal underground rhizome. A young section of the rhizome

[1] Plant Introduction Section, Horticultural Crops Research Branch, Agricultural Research Service, United States Department of Agriculture.

with dormant buds is dug up and set upright or at a slight inclination from the vertical, in a suitable receptacle, with the basal three or four inches covered with soil. The exposed portion soon turns green in response to light. The buds that develop under the soil produce greatly reduced culms, while those which develop above the soil send out short leafy branches. The net effect of the small stature of the slender culm-like rhizome with its short internodes is a deceptive appearance of dwarfness that is often very pleasing to the uninitiated. To the expert, be he professional or amateur, this device is but an obvious humbug.

In another procedure, the culm sheaths, which normally protect the tender growing part of the young culm, are removed prematurely. As a result, elongation of the culm is stopped. Plants of a naturally small stature, and of either type of growth, may be used for this treatment.

Where the climate is sufficiently warm, young plants started from depauperate offshoots of a dwarf form of *Bambusa multiplex* make most satisfactory subjects for tray gardens and miniature mountain landscapes. Bamboos having naturally some bizarre character, such as the shortening of the internodes that occurs in *Phyllostachys aurea, Bambusa ventricosa* and *B. vulgaris,* for example, or the square form of internodes and prominent spiny nodes in *Chimonobambusa quadrangularis,* or the green-striped golden culms characteristic of certain horticultural forms of *Bambusa vulgaris, B. multiplex* and *Phyllostachys bambusoides,* are given special attention in gardens.

Many species and varieties of bamboo are highly esteemed as ornamentals. Plants of various species of *Sasa* and *Phyllostachys* are perhaps most numerous among the bamboos in Oriental gardens, partly because of their ease of culture and their natural decorative value, and partly because, in the Orient, gardening reaches its highest state of development in the warm-temperate climate preferred by these genera. Three tropical species deserve special mention because of their striking appearance and popular appeal. These are the white powdery bamboo (*Lingnania chungii*) of southern China, the monastery bamboo (*Thyrsostachys siamensis*) of Thailand, and the giant bamboo (*Dendrocalamus giganteus*) of India. The first, as yet unknown in the West, has been highly esteemed and even memorialized by Chinese poets and artists since very early times. The last is widely known and greatly admired in the West as well as the East, for the unique size of its culms which attain truly gigantic proportions.

In Japan various parts of bamboo are regularly used for their decorative effect. The full-grown leafy culms are often massed together for temporary background purposes. After the leaves have fallen, the dried culms, with their branches bedecked with colored paper streamers or gleaming lanterns, are set up for all manner of festive occasions. Large bouquet-like arrangements, in which three culm sections of unequal length form the central element, with evergreen branches massed about the base, constitute a more formal type of ornament. In all objects made of bamboo, whether flower vases, ornamental baskets, figurines, children's toys or any of the thousand and one objects of everyday use, the natural decorative value of the culms or other parts of the plant is always presented to advantage.

Bamboo in Papermaking

Bamboo occupies a very important place in the ancient hand craft of papermaking in the Orient. Not only is the greater part of the paper used in the Far East composed of bamboo pulp, but until recently practically all of it was made on

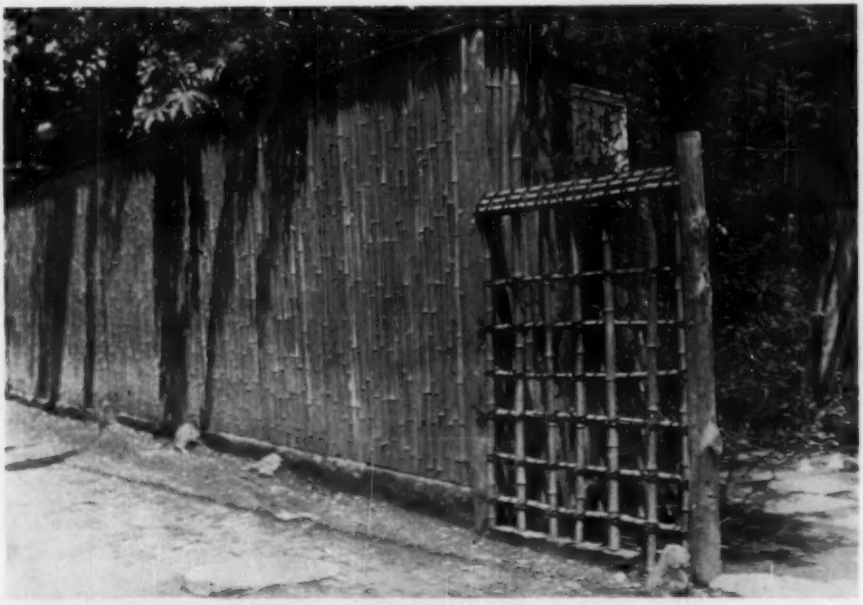

FIG. 1 (Upper). As a graceful living plant, or as a screen, lattice or archway, bamboo enhances the beauty of any scene. Garden fence at Shibuyii, Japan. (P. H. Dorsett photo, from U.S.D.A.)

FIG. 2 (Lower). Stoutly built of resilient bamboo, these poultry crates are light, airy and durable. Easily handled by porters, they may be stacked sky-high without danger of shifting or toppling. Peking. (P. H. Dorsett photo, from U.S.D.A.)

molds, the essential part of which is fashioned from slender strips of bamboo wood.

Establishment of a paper mill is conditioned upon the availability of a sufficient supply of pulp material within easy reach. The industry depends also upon a steady supply of clear water and a cheap source of the digesting materials, such as quick lime, soda ash or potash. The methods employed in the old mills where paper is made entirely by hand are of a very primitive nature and are, for that reason, not adequate for refining the highly lignified tissues of mature bamboo culms. Therefore, the better grades of paper are made from young culms only—those which have not yet put forth their leaves. For making some of the very coarse dark papers of common use for filters, wrappings, etc., mature stems are acceptable. The tips of the mature culms, a by-product of the split bamboo industry, are so employed in southeastern Asia. The time allowed for digestion is very long, often a full year, and the pulping methods are not highly refined. For cheap papers the requirements are less exacting, and a wider range of bamboo species is employed as a source of pulp. In fact, it is probable that any local species in sufficient abundance and available at a reasonable price may be used.

In the construction of the common type of mold, on which the finest paper is still made by hand in the Orient, bamboo is always used. The essential part of the mold is a flexible screen of slender wire-like units fastened together in parallel array by means of hair, silk or ramie. The best screens are made from the peripheral wood of large culms of *Phyllostachys pubescens* or *P. bambusoides*. After preliminary splitting, the raw strips are reduced to the desired size and to a cylindrical form by being pulled through a hole in a piece of steel, after the manner of wire-drawing. In this way wire-like strips of marvelous uniformity and fineness may be produced. Some screens have as many as 32 strips to the inch. The finished screens, after having been treated with lacquer, are objects of great beauty and unbelievable durability. The binding fibers, which correspond to the warp in weaving, are the first part of the screen to wear out. When a screen has been in use many years and can no longer be repaired, the bamboo strips are salvaged and reworked into a new screen.

Bamboo finds numerous other more or less incidental uses in the average Oriental mill where paper is made by hand. The half-stuff is carried from the digesting vat to the bamboo treading trough in bamboo baskets suspended from a bamboo pole. The finished pulp is "combed" by means of a bamboo loop to remove coarse fibers ("shives") which have escaped reduction by digesting and treading. Upon addition of water, after it has reached the dipping vat, the pulp is agitated by means of a bamboo stirring rod to effect an even dispersal of the fibers. The vatman and the drier work by the light of a bamboo lamp at night. Bamboo rope is used on the windlass for applying force to the press. Bamboo forceps are used to pick up the corners of the wet sheets from the block as it comes from the press. Old bamboo culms that are too highly lignified to make pulp by hand methods are commonly used as fuel for drying the paper. The bales of finished paper are often covered with bamboo culm sheaths and bound with bamboo bands. A bamboo tool, combining the functions of a gauge and an awl, is used to space the bands upon the bales and tuck in the twisted ends.

The principal technical problems arising in connection with the use of bamboo for paper pulp in modern mills have been solved, and many variants of the process have been patented in those countries where paper is made on a large scale. At

least one of the several modern paper mills established in China under an earlier regime used bamboo exclusively as a source of pulp, and it is claimed that 90 types and grades of paper were made, ranging all the way from wrapping paper and tissues to bond and ledger.

As a result of long and careful pioneering experiments by William Raitt, and more recent studies by Indian technicians working at Dehra Dun, India leads the Oriental countries in the volume of bamboo pulp produced. Indian mills are now turning out bamboo pulp at a rate approaching 250,000 tons per year, principally from the culms of *Dendrocalamus strictus*. The major portion of this is used for blending, to up-grade inferior pulp made from herbaceous grasses and short-fibered hardwoods. In Thailand a modern mill makes paper entirely from bamboo, but the total amount and the identity of the species used have not been reported. Indonesia and Burma both have plans on foot for building modern mills to convert a part of their vast bamboo resources into paper. Pakistan has just completed an ultra-modern mill designed for an initial production of 30,000 tons of bamboo pulp per year, principally from the culms of *Melocanna baccifera* (Fig. 3). Japan is producing paper by modern methods on an experimental scale and plans for expanded facilities are under way. The species of principal interest there is *Phyllostachys bambusoides*.

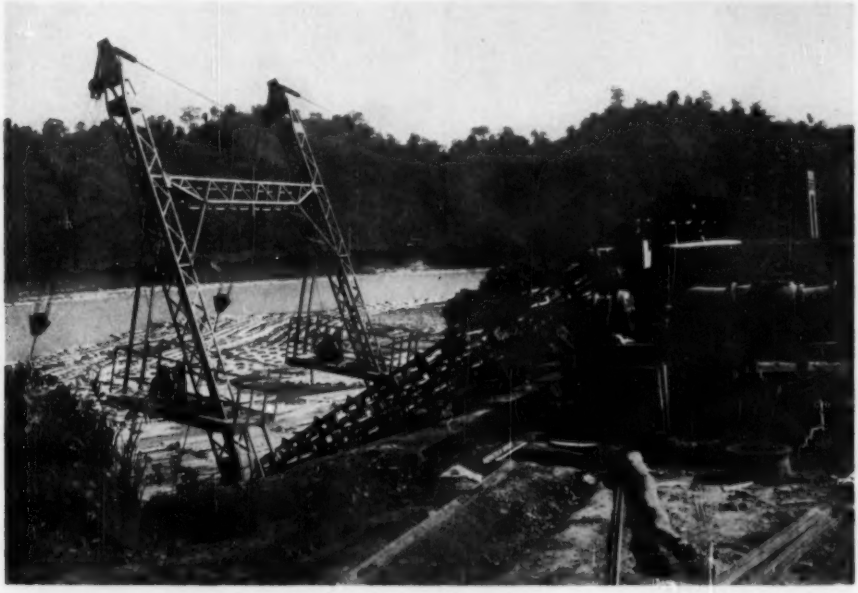

FIG. 3. At the recently completed Karnaphuli Paper Mill, East Pakistan, bamboo will be used to produce 100 tons of pulp per day. Equipment shown was specially designed to lift rafted bundles of bamboo from the river to the flume, by way of which they will reach the mill. (F. A. McClure photo.)

Bamboo as a Textile

A great many objects of common domestic and industrial use are fashioned entirely or in part from woven bamboo.

FIG. 4. Bamboo guards a precious young tree inexpensively and effectively at the Bogor Botanic Garden, Indonesia. (P. H. Dorsett photo, from U.S.D.A.)

These have the qualities of lightness and flexibility, and there is about them an artistic appeal not to be found in any other equally cheap material.

Bamboo has numerous characteristics which fit it especially for weaving purposes: straight grain, ease of splitting, flexibility, toughness, natural gloss and lightness in proportion to volume, to mention the more obvious ones. The individual textile units are long, thin, tangential segments of the outer layer of the culm, with the epidermis occupying the greatest possible dimension. As prepared for most purposes, these units vary up to about eight feet in length, from one-fourth to three-eighths of an inch in width, and from one-sixteenth to three-sixteenths of an inch in thickness. For certain types of basketry and matting these may be much narrower or much wider. For very fine matting the outermost layer is removed to make the strips perfectly flat and to eliminate the unevenness occasioned by the nodal rings, and the finished strips may be but one-sixteenth of an inch or less in width, and exceedingly thin. For certain kinds of sawale (a type of matting common in the Philippine Islands, whence comes the name, and in southeastern Asia generally), the culms are first cracked at several points around each node, then opened by a single longitudinal slit. When the diaphragms have been removed, the culms are spread out flat.

Bamboo in Basketry

In the Orient bamboo baskets and trays enjoy a usage more varied, perhaps, than that accorded any other bamboo article. This is true in the outer world of industry and transportation as well as in domestic circles where there is still much fetching and carrying to be done and where drying is the prevailing method of preserving foods. The Orient possesses no material, other than bamboo, that is available in such abundance or so well suited to the construction of light, convenient, attractive and inexpensive baskets and trays.

Baskets of a design peculiar to the individual need are used by money changers, carriers of sand and earth, tenders of newly hatched chicks, wholesale food merchants, dealers in crude drugs, and peddlers of fish, fruits and vegetables. Baskets in an infinite variety of shapes and weaves are available, particularly in Japan, for the decorative arrangement of flowers and fruits. For the farmer's wife, the herbalist and the maker of candied fruits, bamboo trays provide a cheap, light and convenient means of exposing things to the sun and of gathering them up again quickly when rain threatens. Bamboo baskets and trays constitute an important item of equipment required for many large-scale industrial and commercial pursuits in the Orient. In the

silk industry the mulberry leaves are brought from the field in bamboo hampers, while the silkworms are hatched, and spend the whole of the caterpillar stage, on bamboo feeding-trays. As a fitting finale they are placed, when mature, upon racks fashioned from bamboo in a form suggesting tree-tops where, in the wild free state, their ancestors spun their cocoons. The shape of these spinning racks is cleverly designed, however, in deference to the requirements of space economy.

FIG. 5. Although the bamboo withes from which they are made appear frail and inconsequential, these baskets effectively stabilize a footbridge of field stones near Kao-dien, Hupeh province. (F. N. Meyer photo, from U.S.D.A.)

In southeastern China, pig crates, chicken baskets and tree protectors (Figs. 2 & 4) are made from heavy strips of the culms of *Bambusa tuldoides* and related species. In this same region trays and baskets are woven principally from thongs of *Bambusa textilis*, while certain heavier parts, such as the stays and rims, are usually made from *Bambusa tuldoides* and similar kinds. In more temperate regions, including Japan, various species of *Phyllostachys* are used for all parts of these containers (Fig. 13). In more tropical regions a wide array of species chiefly of the genera *Bambusa*, *Dendrocalamus*, *Melocanna*, *Gigantochloa* and *Schizostachyum*, yield basket-making materials.

Stones used in the construction of dams and in the repair of dykes are held in place by being confined in cylindrical baskets of bamboo of the same general pattern as the pig-crates and tree-protectors mentioned previously (Fig. 5).

Bamboo Matting

Bamboo matting is woven in a great variety of shapes and patterns and is employed in many ways in the Orient. One

sort, of incredible fineness and flexibility, is used in China as the equivalent of bed sheets and pillow cases during summer weather. Long narrow strips of a sturdy tight-woven form are used by itinerant duck-herds for corraling the fowls at night, and by farmers for making demountable grain bins. Fruits and other products which would be spoiled by contact with the soil are spread out to dry on squares or rectangular pieces of coarse bamboo matting. Similar mats are used as overnight covers or during showers to protect farm produce being cured or dried in the sun. Bamboo mats are made in various sizes and weaves for use as a covering for the walls and partitions of bamboo dwellings (Fig. 6) and more temporary structures. Matting of open weave serves to reduce the light to an intensity suitable for orchid culture, while sun-shades and windbreaks of close-woven bamboo mats are often erected for the protection of other delicate horticultural crops. On certain types of water craft, bamboo mats serve as shelters against the elements and on occasion as emergency sails. The "sea anchors" employed to harness the current for steadying boats engaged in fishing or dredging are made of bamboo matting. Fences made of coarse bamboo matting may also serve as windbreaks or screens for privacy.

Most matting is uncolored and depends for its ornamental appeal upon the weave-pattern. Sometimes, however, interesting color-patterns are produced by using dyed strips of various hues. Stage settings are sometimes composed of scenes painted on bamboo matting. Plain bamboo matting is effectively used as a background for the display of paintings and objects of art.

In Japan and the temperate parts of China various species of *Phyllostachys* yield the strips used for matting. In southern China, *Bambusa textilis* is the matting bamboo par excellence. In the Philippine Islands matting is made principally from the culms of *Schizostachyum* spp., while in the more southerly parts of Asia and in Indonesia and adjacent islands those from *Bambusa, Dendrocalamus, Gigantochloa, Melocanna* and *Schizostachyum* are used.

We usually think of matting as a woven product, but there is a kind called "smooth matting" made in China by another method. These mats are constructed by stringing together, edge-to-edge, partially split sections of the culms of *Phyllostachys pubescens*. Flawless sections are selected from the lower middle portion of large culms where there is the least taper and no branches. These are cut to a length precisely equal to the width of the finished mat. The external nodal projections are planed or scraped down to the level of the rest of the culm surfaces. Each section is then split into strips about an inch in width, and these are kept in their original order. The fragments of the diaphragms are now removed and the strips are again split at intervals of perhaps an eighth of an inch this time through only about two-thirds of their length and alternately from the two ends. These inch-wide strips may now be flattened out. They are laid, one by one, outer side down, on a flat surface and drilled tangentially with three pairs of holes (one pair at the middle and one near each end) always precisely located. The different sets of strips from the several culm sections are now matched, planed on the edges where necessary and then strung together on heavy cotton cord. Such mats are used chiefly for covering beds and cots for summer use in warm climates. The upper side, which is formed by the outer waxy surface of the bamboo, takes on a pleasing natural polish with use and provides incredibly cool and comfortable sleeping conditions in the hottest weather.

Bamboo Rope

Ropes made from bamboo are used more extensively in China, perhaps, than

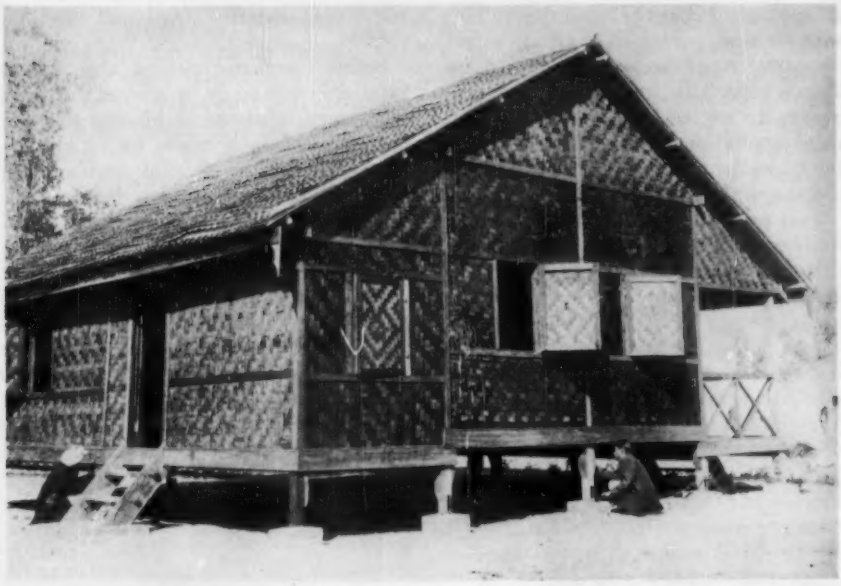

FIG. 6 (Upper). Hardwood framed house with walls of bamboo matting and roof of bamboo shingles (*Bambusa polymorpha*). A modern adaptation developed in Burma. (F. A. McClure photo.)

FIG. 7 (Lower). The muli bamboo (*Melocanna baccifera*) is the principal material used for housing and industrial purposes in East Pakistan. Millions of culms of this bamboo come into Chittagong each year by raft. (F. A. McClure photo.)

in any other Oriental country. They have several points of distinct superiority over ropes made from other fibers. This is especially true where the rope is frequently wetted or subjected to an unusual amount of abrasion, as in the drilling of wells, the pumping of salt-brine and the towing of boats.

Two general methods of manufacture are used. The easier and more common method is essentially like that by which rope is made in the West by hand, the same twisting devices and "rope walk" being employed. It consists simply of the operations involved in twisting the individual strips together. The primary units may be further united, by twisting, into successively larger units until cables of prodigious size, up to two feet in circumference, may be made. Such great ropes are employed only in constructing mighty cable bridges or in the repairing of important dikes during a flood.

A much more durable type of rope is plaited or braided in a tubular form, but this can be made only in rather slender sizes. The work is performed in a tower, and the rope is lowered to the ground as it is finished. It is much more tedious to make this kind, but it has a considerably greater tensile strength per unit of weight than the twisted sort. For tracking purposes (towing riverboats by man power), the superiority of the braided rope is outstanding. Being of open construction and consisting of coarse units, it holds less water and dries more quickly after having been submerged. Again, in places where the towpath swings around the convex side of a rock cliff, the rope often rubs against the rough surface under considerable tension. When the plaited type of rope becomes damaged by this hard usage, individual strips may be replaced, thus restoring it more or less completely to its original condition. When this rope becomes so aged or worn that it must be discarded, it is cut into convenient lengths, dried and used for torches.

Small bamboo ropes of the twisted type are commonly employed for such temporary functions as binding together the units of rafts made up of lumber, fuel wood or bundles of bamboo, for transportation by water. When these rafts are moved by means of the stream current or the tide instead of being towed, guiding, braking and anchorage are miraculously accomplished by means of stone-weighted wooden anchors attached to the stern by means of bamboo rope, and floated intermittently upon smaller, trailing, bamboo pilot rafts. The passage boats operated on the inland watercourses are towed by means of large twisted bamboo ropes or cables. Bamboo ropes are used in western China for drilling salt wells and for hoisting brine.

Bamboo as a Building Material

In vast areas, bamboo is the one material that is sufficiently cheap and plentiful to fill the tremendous need for economical housing (Fig. 7). Bamboo is employed in many ways, often as much for its ornamental value as for its superior fitness in homes built primarily of more substantial and more costly materials. It is eminently suited and economically desirable for the construction of all parts of a house. It serves admirably for the builder's scaffolding as well. The natural units, or culms, are of a size and shape that make handling, storing and processing both convenient and inexpensive. The characteristic physical structure of the culms gives them a high strength-weight ratio. They are round or nearly so in cross section and usually hollow, with rigid cross-walls strategically placed to prevent collapse on bending. The strong hard tissues of great tensile strength are most highly concentrated near the surface of the culm walls. In this position they can

function most effectively, both in giving mechanical strength and in forming a firm resistant shell. Because of the nature of their substance and grain, bamboo culms are easily divided by hand into shorter pieces by sawing or chopping, or into narrow strips by splitting. No costly machines are required; simple tools suffice (Fig. 8). The natural surface of most bamboos is clean, hard and smooth, with an attractive color when the culms are properly matured and seasoned. Bamboos have little waste and no bark to remove.

FIG. 8. As demonstrated by this bamboo worker at Chittagong, East Pakistan, who is making lashings to take the place of nails, no complicated or costly machinery is required to process bamboo for building purposes. (F. A. McClure photo.)

The construction of bamboo walls is subject to infinite variation, depending on the strength required for resistance to natural forces, such as earthquakes and hurricanes, and protection from rain and ordinary winds. Either whole culms or longitudinal halves may be used. They are arranged either horizontally or vertically. In the vertical position they function more effectively and are more durable because they dry more quickly after a rain.

For practical reasons window and outside door openings are kept to a minimum, though they must be sufficient to supply the needed light and ventilation. They may be framed with wood or bamboo. The doors themselves may be wood, or they may be woven bamboo matting stretched on a bamboo frame. A panel of bamboo boards is sometimes set in a hardwood frame. A sturdy gate-like barrier may be constructed of whole bamboo culms. Bamboo window bars often take the place of iron or steel ones, and bamboo window shades are common.

Serviceable and attractive floors may be made entirely of bamboo. The prin-

cipal features are the supporting beams, which are part of the basic frame of the house, and a floor covering. The floor covering may be of small whole culms, strips, or bamboo boards made by opening and flattening out whole culms. In this last case the floor is generally fastened down by thin strips of bamboo laid transversely and secured to the supporting members by thongs, wire lashings or small nails, according to local preference and the materials available. Bamboos are utilized to excellent advantage in roof construction because of their high strength-weight ratio.

It is common practice in the Orient to complete scaffolding to its full ultimate height before a building is started. In the more tropical regions this is topped off by a thatched roof as a protection against sun and rain during building operations.

Bamboo scaffolding is very often erected against apartments and private dwellings to support bamboo matting for shedding sun and rain during summer. Bamboo screens give privacy in crowded communities.

Bamboo Shelters and Other More or Less Temporary Structures

One of the simplest examples of a temporary bamboo structure is the roadside shelter erected by the impecunious dispenser of cheap refreshments who expects to carry on his business at a particular spot only during the course of a local fair or the run of an itinerant theatrical troupe. Such a shelter may consist of little more than four bamboo posts set in the ground and surmounted by a rough lattice of bamboo culms to support a thatch of grass or palm leaves. If the proprietor spends the night there, three sides may be covered with bamboo matting supported by a few extra bamboo crossbeams and braces. Shelters for an agricultural or industrial fair or flower show are put up by a commercial matshed builder on a larger scale and more securely. Itinerant theatrical troupes employ bamboo structures of a distinctive architecture, tall and narrow, with the walls often covered with gaudily decorated mats, and surmounted by ornamental devices of traditional rococo design. The floor, which is elevated several feet above the ground, is made of thin wooden planks laid on bamboo beams and held in place by thin strips of bamboo bound down by bamboo thongs. The top-heavy structure is held erect by means of long bamboo braces, to which is often added the security of bamboo guy-ropes.

Mention of these theatres, built for short gala festivals, calls to mind the much more highly ornamented and even more transient "triumphal arches" or gateways erected over the road to be traveled by an honored guest or a conquering hero. In these triumphal arches the versatility of bamboo as a building material and a decorating medium is exhibited to fine advantage.

Bamboo in Oriental Furniture-Making, Coopery and Joinery

The furnishings of a house may be more or less predominantly of bamboo construction, depending upon the pecuniary circumstances or the artistic tastes of the family. The kitchen stools, the baby's play chair, the sofa used for the afternoon siesta in torrid weather, and the settee on the veranda or in the garden pergola are all articles of furniture commonly made of bamboo. The species used for this purpose vary locally, but in the more temperate parts of the Orient most of them belong to the genus *Phyllostachys*. Now and then one will see a treasured settee or a tea-table fashioned from the brilliant purplish-black culms of *Phyllostachys nigra*. In more tropical areas various species of *Bambusa* enter into funiture making. Bamboo dowel-pins are commonly employed

by carpenters for joining boards edge-to-edge in the making of certain articles of furniture such as beds and wardrobes. The best dowel-pins are made from the rind-wood of *Arundinaria amabilis*. *Phyllostachys pubescens* is also used.

Bamboo enjoys enormous usage in the Orient in the form of hoops. The large wooden tubs used in the pickling and food-processing industries are commonly bound with bamboo hoops (Fig. 10). These are more resistant than iron hoops to the action of salt and vinegar. While wooden water buckets and wash basins are almost always first bound with iron hoops, when at length these give out the itinerant repairman replaces them with bamboo.

Bamboo hoops are always made up of a number of slender strips (Fig. 9). These are fabricated into a circular unit of the desired dimensions either by twisting or by plaiting. The plaited form is more durable and probably has a greater tensile strength per strip unit. The twisted form is easier to make and is, therefore, cheaper. An important feature of the technique of making both sorts is keeping rind or outer surface of the strips always on the convex side of a bend or curve.

FIG. 9. The versatility of bamboo is explored by the skill and ingenuity of the craftsman in adapting his simple tools to the task of processing the culms. Aged cooper making bamboo hoop-stock at Oimachi, Japan. (P. H. Dorsett photo, from U.S.D.A.)

Bamboo hoops of the plaited type are indispensable in the oil-pressing industry, being employed to form, along with ricestraw, the outer shell of the cylinder which confines the oil-bearing meal while it is under pressure. The meal is wrapped in straw in the form of disk-shaped

packages, each supported on its periphery by several bamboo hoops. The units are placed side by side in the primitive wooden press which is operated by hand on the percussion principle.

We do not ordinarily think of bamboo as a wood appropriate to the joiner's art. However, the making of the bamboo buckets and tubs used as containers for cooked rice is a trade in itself. Some thirty-odd tools, each with a special function, compose the kit of the maker of these bamboo vessels!

Bamboo Bridges

A very ingenious device is often erected for transporting persons, goods and animals across deep swift streams, particularly in the mountainous borderland between China and Tibet, where few bridges are available. This device consists of a strong cable fashioned of split bamboo and having a diameter commensurate with its length and the weight of the load it is likely to bear. The following description is taken from E. H. Wilson, "A naturalist in western China", vol. 1, p. 164 (1913):

"These simple but extremely useful structures consist of a bamboo hawser stretched across the stream usually from a higher to a lower point; if the stream is moderately narrow the question of incline is of less importance. The hawser may be anything from 8 inches to a foot thick, and being heavy sags considerably in the middle. To cross one of these cable bridges a person is supplied with a length of strong hempen rope hanging free from a saddle-shaped runner of oak or some other tough wood. The runner clips the cable, and the hempen rope is fastened under and around the legs and waist to form a cradle. When all is properly secured the person throws one arm over the top of the runner, gives a slight spring, and glides down the inclined cable at an increasing speed. The impetus obtained in the downward rush carries the passenger over the central dip and more or less up the lesser incline on the opposite side. If the momentum is insufficient to land the person, the remaining distance has to be traversed by taking hold of the hawser and hauling hand over hand. Crossing by these bridges is fearsome work until one is accustomed to it. It is speedily accomplished, and there is practically no danger so long as one keeps a cool head and the ropes do not break. It is a common sight to see men with loads and women with children on their backs cross these bridges. But heavy loads are usually fixed to the runners and hauled across by a rope attached to them".

These cables are used in another very interesting manner to expedite and make safer the crossing of some of the streams which are too swift for ordinary navigation. Here the cable is suspended at a height of a few feet above the surface of the water, and instead of the "saddle", a boat is attached to the wooden "runner". Then the force of the current, which would otherwise carry the boat downstream in spite of all human efforts, is transformed by means of an oar or rudder set at the proper angle into lateral thrust which carries the boat quickly from one bank to the other (Fig. 11).

The next natural step in the evolution of these structures is as a suspension bridge which may well be considered the prototype of our modern ones, of which the Brooklyn Bridge is a well-known example. Thinly populated mountainous Western China boasts the most magnificent of these, and for the following description we are likewise indebted to E. H. Wilson (*op. cit.*, p. 171):

"This remarkable structure is about 250 yards long, nine feet wide, built entirely of bamboo cables resting on seven supports fixed equidistant in the bed of the stream, the central one only being of stone. The floor of the bridge rests across ten bamboo cables, each 21 inches in circumference, made of bamboo culms,

FIG. 10. In the Far East massive and ingeniously contrived ligatures of bamboo add beauty as well as strength to wooden casks and tubs. Tokyo. (P. H. Dorsett photo, from U.S.D.A.)

split and twisted together; five similar cables on each side form the rails. The cables are all fastened to huge capstans, embedded in masonry, which are revolved by means of spars and keep the cables taut. The floor of the bridge is of planking held down by a bamboo rope on either side. Lateral strands of bamboo keep the various cables in place, and wooden pegs driven through poles of hard wood assist in keeping the floor of the bridge in position. Not a single nail or piece of iron is used in the whole structure. Every year the cables supporting the floor are replaced by new ones, they themselves replacing the rails. This bridge is very picturesque in appearance, and a most ingenious engineering feat".

Bamboo in the Fishing Industry of the Orient

To most Americans "bamboo" and "fishing" are ideas almost as intimately associated as are the words "bread" and "butter". Indeed, for many the term "fishing-pole" is synonymous with the word "bamboo". In the Orient, however, this association is very much more profound and intimate, as well as more ancient. This fact may be verified by anyone, even though he may not be privileged to see the varied bamboo gear that is an essential part of the Oriental fisherman's paraphernalia. It is sufficient to look up the names of these objects in a Chinese dictionary, for it will be found that a great many of these complex terms (ideographs and pictographs) contain the symbol for bamboo. This fact signifies that even before their names were first reduced to writing, bamboo was employed in the making of the devices themselves. It is perhaps sufficient for our purpose to mention a few of them: traps, weirs, sluices, barriers, poles for hook-and-line fishing, spears, sea-anchors, floats, trays and poles for drying fish and baskets for transporting them, netting needles, poles for drying nets, punting poles, and scaff or dip-nets, including karojals and salambas. The dredges, punting poles, sieves and sea anchors of Oriental clam-dredging equipment are all made of bamboo.

Bamboo in the Export Trade of Oriental Countries

Export of bamboo and bamboo products from Oriental countries other than China and Japan is negligible. The bulk of the bamboo trade of China is carried on with adjacent countries.

Western countries draw upon the Orient chiefly for ordinary bamboo poles, Tonkin cane, split bamboo and bamboo shoots. In the exportation of bamboo poles for use in their natural state as fishing rods, etc., Japan leads by a wide margin. All, or nearly all, of these poles come from species of *Phyllostachys*.

Tsinglee cane, also called Tonkin cane (*Arundinaria amabilis*), falls in a distinct category. It is produced exclusively in a small area in the hinterland of Canton, in southeastern China, and under the earlier regime practically the entire production was shipped abroad, principally to England, Germany and the United States. Several special processes are involved in the preparation of the culms for export. The culms of this bamboo have so many splendid qualities and meet such important technical speci-

FIG. 11 (Upper). Where traffic is light, a costly bridge would be no great improvement over this simple bamboo cable. With the aid of a sturdy hardwood clip, it uses the force of the current to propel the heavily laden ferry boat to and fro across the Siku River on the border of Tibet. (F. N. Meyer photo, from U.S.D.A.)

FIG. 12 (Lower). Bamboo provides the yoke and the "bed" for ox-carts, the principal means of transporting building materials in India, Pakistan and many other parts of the Far East. (F. A. McClure photo.)

fications that they are greatly in demand. The larger canes are extensively used, particularly in Great Britain and the United States, in the making of various articles for sports, for example, split-bamboo fishing rods and vaulting poles. Medium-sized canes, under an inch in diameter, are used for making skiing staffs, garden stakes, handles for collecting nets, etc., while the smaller sizes go into flower stakes, pennant sticks, etc.

India formerly exported, principally to England, considerable quantities of Calcutta cane (?*Dendrocalamus strictus*), from which split-bamboo fishing rods were made originally. Since the discovery of the superiority of Tonkin cane for this purpose, however, the exportation of Calcutta cane has dwindled to almost nothing. Burma Cane has taken its place, at least in the United States, where it is much used, in the natural state, unsplit, for making surf rods. Its botanical identity has also not been determined.

Southeastern China is the chief source of split bamboo, the principal use of which in Western countries is the making of coarse brooms for street cleaners. It is also used to a limited extent in handcraft classes as a material for weaving. This product comes principally from *Bambusa textilis*.

Edible bamboo shoots are exported from China and Japan chiefly to adjacent countries. While the exportation of this commodity to Western countries has been small in total volume, it reaches a wide geographical area, and the growing taste of Western peoples for Oriental food is increasing the demand. This augmented demand is being met, at least in part, by the canned product. It is probable that the raw shoots exported have consisted almost exclusively of the dormant winter shoots of *Phyllostachys pubescens*. The canned shoots from Japan and central China also come from this species, while those from southeastern China are supplied by *Sinocalamus beecheyanus* and *S. latiflorus*. It appears that small quantities of dried shoots of *Bambusa sinospinosa* and the Henon bamboo, a form of *Phyllostachys nigra*, are exported from southeastern China to nearby countries. It is estimated by Chinese restauranteurs in the United States that the annual importation of bamboo shoots in cans or tubs currently amounts to about one million dollars. They come principally from Japan, Hong Kong and Formosa.

Bamboo in Transportation

Some idea of the importance and the extent of the use of bamboo in Oriental transportation may be conveyed by the following random list of adjuncts and appurtenances: rafts, punting poles, tug- and tracking-cables, stay-ropes, anchor ropes, sail covers, hoists, landing stages (both floating and fixed), fathoming-poles, bilge-pumps, carrying poles, baskets of various design, tung-oil buckets, pig- and chicken-crates, tally sticks, matting, yokes and beds for ox-carts (Fig. 12). Calking material is commonly made of shredded bamboo (prepared by scraping the culms) imbedded in a putty composed of lime and tung oil.

Bamboo on the Oriental Farm

The Oriental farmer may or may not have his own grove of bamboos for the production of shoots to be eaten or culms to be fashioned according to his various needs. In any case, whether he grows his own materials or buys them elsewhere, bamboo is an important factor in his daily life.

Perhaps in no other Oriental industry does bamboo play a more varied role of usefulness than it does in agriculture. In fact, so many bamboo tools and devices are used on the farm and in the garden, as well as in the household itself, that it is not feasible to discuss them all in the present paper.

Certain bamboo articles are indispen-

FIG. 13. Bamboo shoots (*Phyllostachys pubescens*) are taken to market in bamboo baskets of light but sturdy construction. The rectangular shape favored in Japan makes for economy in packing the shoots and in accommodating the baskets. (P. H. Dorsett photo, from U.S.D.A.)

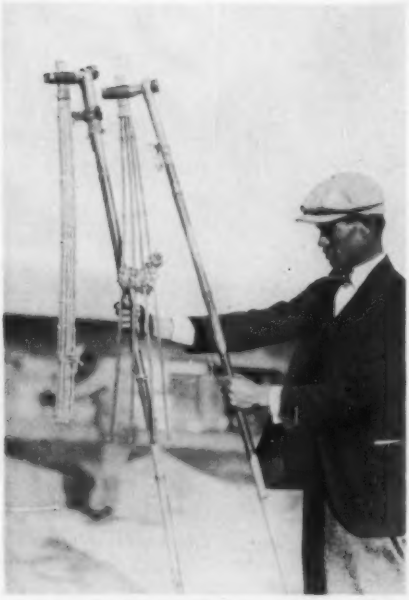

FIG. 14. Flexible and resilient bamboo, grown on the place, provides the Oriental farmer the wherewithal to make his own threshing machine. (P. H. Dorsett photo from U.S.D.A.)

sable to almost every kind of farm work. There is hardly a single activity which does not involve, sooner or later, directly or indirectly, the use of baskets or trays. In many areas bamboo carrying poles are an inseparable adjunct to the use of baskets, whenever there is something to be moved from place to place. In the culture and harvesting of field crops the following bamboo devices and appurtenances come into play at one time or another: fences, irrigation wheels and irrigation pipe, well-sweeps, handles for hoes, rice-cultivating rakes and other tools, flails (Fig. 14) and threshing boards, and demountable grain-bins made of narrow strips of bamboo matting erected in a spiral.

The hill tribes of Hainan, the Philippine Islands and the adjacent mainland of Asia harvest their rice in short "hands" made up of the heads plus a six- or eight-inch portion of the stalk. These "hands" are cured on a long narrow rack consisting of a row of posts set firmly in the ground with slender bamboo culms bound to them in a horizontal position at close intervals, and to a height of about six feet. The "hands" of rice are thrust between these bars in close order and allowed to remain there until they are thoroughly cured before being removed to the granaries. A narrow thatched roof protects them from rain. In the threshing, winnowing and transportation of the grain, bamboo baskets, trays and scoops are all-important.

Wherever the crops are of such a nature as to require protection from the depredations of wild creatures, not to mention domesticated carabao, pigs and chickens, bamboo fencing comes into play. As for the birds, against which fences are of no avail, scarecrows of infinite variety are fashioned more or less exclusively out of bamboo.

Against insect enemies fruit growers bring bamboo spray-guns into play. In the citrus groves of southern China, where a certain species of predacious red ant is colonized on the trees to keep down parasitic scales and other insects, bamboo poles serve as a means of inter-tree transit for the ants. As the harvest begins to mature, bamboo poles serve as supports for over-laden branches. And when the fruit is ripe, it may be removed from the tree by means of bamboo poles equipped in various ways. When twigs of choice trees are inarched, small potted stock-plants are held in place within the tree by long bamboo stakes.

The care, protection and control of livestock utilizes bamboo fences and shelters, feeding troughs and rearing crates, and leading staffs for vicious bulls. The duckherd always carries a long-handled, soft-lashed, bamboo whip

with which he gently chastizes the laggards.

In Oriental vegetable and flower gardens we find bamboo poles for supporting the vines of beans and melons, and smaller stakes for other weak-stemmed plants. The sprinkling buckets are equipped with bamboo spouts. Windbreaks are often used as a protection against unseasonable blasts from the North, and, for certain delicate plants, bamboo sun-screens are sometimes erected.

Within the household are found, in addition to the various articles of furniture, bamboo brooms, rakes for gathering fuel, fire-blowing tubes, laundry poles, chopsticks, serving trays, colanders, sieves, graters, etc. It is a common practice among the more primitive peoples of the Orient to use sections of large bamboo culms as water buckets and for storing oil and other liquids or for conveying them from place to place.

Bamboo as a Farm Crop in the Orient

The rural culture of bamboo in the Far East varies in its nature all the way from the intensive and detailed husbandry (Fig. 16) characteristic of Oriental agriculture and horticulture, in general, to a casual treatment in which the plants are practically allowed to shift for themselves after they have been set out. The bamboos grown as a farm crop may be classified, roughly, into three groups: those grown for their edible shoots alone, those grown for both shoots and mature culms, and those grown for the mature culms only.

FIG. 15. In the culture of *Sinocalamus beecheyanus* and other clump bamboos for their edible shoots, the base of the plant is renovated each year in December or January; earth is heaped up afresh around it, and fertilizer is applied. Shoots are produced from July to September. Canton, China. (F. A. McClure photo, from U.S.D.A.)

There are two general types of cultural practice, corresponding to the two types of rhizome growth. Bamboos of the clump type (those which have sympodial or determinate rhizomes), such as species of *Bambusa, Dendrocalamus, Schizostachyum* and *Lingnania*, are cultivated by preference on level land, since the shallow rhizomes of this type of bamboo sometimes are at a certain disadvantage in hillside culture. Even when grown on level land, many of these bamboos thrive best when some fresh earth is thrown over the rhizomes each year. In the culture of this type of bamboo for shoots (*Sinocalamus beecheyanus* and *S. latiflorus*), as carried on in southeastern China, the earth is pulled away from the base of each clump every year in December or January and the dead wood of old rhizomes is removed. The earth is then heaped up afresh and the systematic application of fertilizer, usually diluted urine, is begun. In addition to protecting the rhizomes and roots from undue exposure and drying, these heaps of earth serve to protect the young shoots from the light until they are large enough to be harvested. This is important, for the action of sunlight spoils their flavor (Fig. 15).

Bamboos of the spreading type (Fig. 16) with slender, indeterminate rhizomes, such as species of *Arundinaria* and *Phyllostachys*, are grown on both level land and hillsides. Aside from the question of fertility, which is usually higher in level land, hill land seems to be preferred by bamboos of this type. This may be due in part to their abhorrence of poor drainage. It may be, also, that the slope of the land affords a certain stimulus which would explain the use by the rhizomes of a greater vertical range of the soil strata, a condition evident in hillside cultures. This postpones the competition between rhizomes which soon becomes apparent in plants grown on level land.

Culture of bamboo exhibits a great range of care. One extreme is represented by complete neglect of the grove other than harvesting the shoots at the appropriate time or cutting the culms when they are mature. One degree of improvement comes with selection of those shoots which are to be allowed to reach maturity, and the intelligent choice of culms to remove, looking to the maintenance or increase of the productivity of the grove. A further improvement is represented by removal of weeds and brush from the grove once a year. When the careful farmer sees that the soil has become choked with an accumulation of old rhizomes, he renovates the grove or shifts its location.

In addition to being grown as a farm crop, bamboo is extensively used throughout the Orient to form living hedges, barriers and windbreaks. While these are usually informal, they are sometimes trimmed and restricted rather systematically. Bamboos of the clump type are preferred for these purposes in areas where they are sufficiently hardy. Unlike bamboos of the running type, they form rather compact tufts, spread slowly, and do not encroach upon adjacent land. For small, formal or informal, ornamental hedges in tropical and subtropical areas, varieties of *Bambusa multiplex* are generally used. In more temperate regions dwarf species of *Phyllostachys, Sasa* or some of the other related genera are employed. For the protective barriers about villages so commonly seen in the more tropical parts of the Orient, large spiny-branched bamboos of the genus *Bambusa* are employed. The shoots of *Bambusa sinospinosa* and *B. blumeana* are edible after parboiling. In China the former are usually dried for consumption during the winter season. The latter are used to a very great extent as an esculent in the Philippine Islands.

FIG. 16. Japanese bamboo gardens are admirably managed. The exacting procedures for spacing the culms and harvesting the edible shoots require care, skill and experience. The garden of Sankichi Ishida, near Tokyo, Japan. (P. H. Dorsett photo, U.S.D.A.)

Bamboo in the Prevention of Erosion

Although the potentialities of bamboo as a means of preventing erosion on steep slopes have never been fully exploited in the Orient, the plant has been consciously used to excellent advantage for this purpose on levees and dikes. Bamboo groves of the spreading type on mountain sides incidentally serve this very important function to a much greater extent than is generally realized.

Uses of Bamboo Culm Sheaths

Bamboo culm sheaths are husk-like structures which completely clothe and protect the young culm or shoot. The base of each sheath is attached to the culm at a node. In most bamboos the sheath falls away from each successive node, beginning at the basal ones, as soon as the internode stops its growth in length; in some the sheaths persist and gradually disintegrate in place.

The culm sheaths of certain species of bamboo, particularly of the genera *Bambusa, Dendrocalamus* and *Phyllostachys*, have special characteristics in respect to size, texture, toughness and flexibility, which suit them for various purposes. The flexible sheaths of several of the larger species of *Phyllostachys*, for example, are commonly employed, in both China and Japan, as covers for earthenware jars in which certain food products are stored. Other foods are regularly wrapped in these flexible sheaths for display and retail disposal (Fig. 17). In Japan, slender strips of this same type of sheath are widely used in place of twine and in nurseries as a substitute for raffia. They are moistened to increase their toughness while being tied.

In southern China the sheaths of a large thorny species (*Bambusa sinospinosa*) are torn into narrow strips to serve as the weft of coarse sandals. Here also woven bamboo casks lined with the broad stiff sheaths of *Sinocalamus latiflorus* are commonly employed for transporting incense powder. In central China the sheaths of the larger species of *Phyllostachys* are used to line these incense casks and to serve as a protecting cover for bales of the cheaper grades of paper. In various localities in the Orient, bamboo culm sheaths are employed as a waterproof and sunproof lining for inexpensive hats.

In Oriental hand printing and block-print making, the paper is laid upon the inked block. A clear and uniform impression is then insured by rubbing the paper with a pad known as the "baren," a term borrowed from the Japanese. The baren has a firmness suited to the peculiar needs of the work to be done. It is basically a thin disk of wood padded with several layers of tough paper. The outer covering is always a smooth, tough, flexible bamboo sheath. In both China and Japan the baren used by printer and block-maker is covered with a culm sheath from a large species of *Phyllostachys*, usually *P. pubescens* or *P. bambusoides*.

One often sees, in the more tropical parts of the Orient, scarecrows made from large stiff culm sheaths. The sheaths are either suspended by a short cord from the tip of a bamboo pole thrust into the ground at an oblique angle, or simply impaled upon a short stick set upright. As the sheath swings about in the breeze, the pale, polished, inner surface and the dull outer one reflect the light differentially, exaggerating the effect of its motion.

Conclusion

This account only begins to cover the phases of the utilization of bamboo. The conscious aim has been to present an intimate view of selected aspects in those areas of the Far East where its perfection is most remarkable. The motive has not been to suggest that we should try to imitate the ways of the East, but

FIG. 17. This Japanese lunch, ready "to go", acquires a special attractiveness from the crisp texture and harmonious beige and russet brown coloring of the bamboo culm sheath wrapping. (P. H. Dorsett photo, from U.S.D.A.)

rather that we should appreciate anew the genius that has given us such a rich heritage, and that we should recognize and ponder again the remarkable versatility of this group of plants.

Numerous introductions of living bamboos have been brought into the United States by private individuals and through governmental agencies. Europe has no indigenous bamboos, but introduced species are found in gardens and parks wherever the climate is sufficiently mild. We have growing in the United States more than 100 species and varieties, representing nearly every part of the globe where bamboo is found. And yet, though the first introductions probably were made nearly a century ago, and though bamboos are highly esteemed and cherished in many individual collections, no species has yet established itself securely and indispensably in a single major phase of our economy.

When we know more about the technical characteristics of the different kinds of bamboo and their peculiar adaptabilities to specific industrial purposes, we shall be in a position to avail ourselves more fully of the immense potentialities of this group of plants. Since we live in the age of machines and of large-scale production, we shall need to adapt modern techniques developed in the West and mechanize old ones long employed in the hand crafts of the Orient, before we can succeed in introducing bamboo into our industrial economy to any important extent. Meanwhile we should continue to search for and introduce outstanding bamboos for trial and study.

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Yerba de la Fleche—*Arrow and Fish Poison of the American Southwest*

Analysis and toxicity tests of the latex obtainable from this shrub, previously not reported, are presented here.

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Sapium is a genus of the Euphorbiaceae. This family embraces around 7,000 species distributed over the temperate and tropical world. A number of the Euphorbiaceae are of great economic importance. *Hevea Braziliensis*, chief source of natural rubber, *Ricinus communis* and *Croton tiglium*, from which castor and croton oils are obtained, all belong to the Euphorbiaceae.

Sapium species are characterized by yielding a milky, irritating, often poisonous juice. More than 100 species have been described. Several of these, including *Sapium biloculare* (10), are native of the Southwest, covering large areas of Arizona, Sonora, Mexico and Baja California.

Historical

The early Spanish explorers of the Southwest report use by the native Indians of certain shrubs as sources of poison for their arrows. Standley (8), referring to *S. biloculare*, states: "The juice is poisonous as in other species and in Baja California the finely chopped branches are thrown in water to stupefy fish. Exposure to the smoke from the burning wood or sleeping in the shade of the tree is said to cause sore eyes. This is probably the plant to which Claverigo (Historie de la California, 1789) makes reference as follows: 'Among the few plants of California there are some harmful ones of which is the certain shrub called by the Spaniards of that region "Palo de la Fleche" for from it the Indians dwelling along the coast of Sonora obtain the terrible poison with which they poison their arrows so as to cause mortal wounds'". According to Watson (9), "The Mago in the Opata language is a small tree containing a deadly juice which flows on making a slight incision in the bark. The natives rub their arrows in it and for this reason call it Arrow Grass. On the whole it seems probable that the 'Yerbe Mala' (*Sebastiana bilocularis*) or 'Yerba de la Fleche' yielded or formed the standard arrow poison of the Opata".

According to Lewin (6), the Malay natives used the sap of *Sapium indicum* to stupefy fish, and *Sapium aucuparium* was applied in arrow poison because of the corrosive action of its latex on tissue.

Characteristics

S. biloculare resembles the common oleander (*Nerium*) in leaf, stems and cluster growth, but the flowers are much less conspicuous in *Sapium*. In Arizona (5) the shrub has a maximum height of around 15 feet and a maximum stem diameter of approximately two inches. It is found in sandy washes and on hill sides among lava boulders at elevations of from 800 to 2,000 feet. *Sebastiana pavoniana*, also of the Euphorbiaceae, is similarly native in Sonora. Like those of *Sebastiana*, the seeds of *S. biloculare* are infested with the larvae of a small moth which produces the so-called

"jumping beans". The larva, stimulated by the warmth of the hand, snaps into action, causing the seed to perform its jumping antics.

Previous Work

In 1940 Leslie N. Goodding (4), then botanist with the U. S. Department of Agriculture Soil Conservation Service, shipped to the writer a sample of the shrub. It was ground and the water extract tested on fish with no effect. Drying in shipment probably lowered the solubility of the toxic materials.

Referring to his experience in collecting the shrub, Goodding states: "The milky juice gotten into the eyes, even in minute quantities, causes extreme pain for hours".

A search of the literature did not disclose any analytical work on this species.

Through the kindness of Mr. E. L. Breazeale of the Chemical Department of the Agricultural Experiment Station at the University of Arizona, Tucson, a file of correspondence was made available, covering his contacts on this subject with the Museum of Anthropology, University of Michigan; Museum of New Mexico; Department of Agriculture, Beltsville, Maryland; and the Botany Department, University of California. No record of any analytical studies on *S. biloculare* was obtained from these sources.

In 1950 a sample of *S. biloculare* was kindly collected and shipped to the California Institute of Technology at our request by Wm. P. Supernaugh, Superintendent of the Organ Pipe Cactus National Monument near Ajo, Arizona. Subsequent collections of the latex of the shrub were made at this location by the writer.

Experimental

Initial work on *S. biloculare* was carried out on the leaves, comparing their toxicity with leaves of the common oleander. Distilled water and 50% ethyl alcohol were used as solvents; room temperature for 72 hours and water bath for three hours as extraction methods. Results of these tests are shown in Table I.

TABLE I

TOXICITY TESTS ON LEAVES OF *Sapium biloculare* AND COMMON OLEANDER, CALCULATED TO DRY BASIS

	Water Ext.	50% Alc. Ext.	Toxicity to guinea pigs
	%	%	
Sapium leaves	22.5	...	Non-toxic
" "	...	27.0	" "
Oleander leaves	...	11.7	Toxic

These extracts were fed to guinea pigs in doses of 0.10 to 0.75 grams solids. The *Sapium* extracts were non-toxic. 0.50 grams of the oleander extract proved fatal.

Methods of Collecting the Latex. Because of their small size, *Sapium* stems yield only a few drops of latex. Various methods were tried for extracting it. Preliminary tests on leaching the finely chopped stalks and branches with water were unsatisfactory because of contamination with other water-solubles. The method adopted consisted of making a longitudinal slash with a knife through the bark and compressing this area by bending the stem. This causes droplets of latex to ooze from the cut. These drops can then be picked up with a small dropping bottle equipped with a rubber bulb and glass collecting tube. A small amount of distilled water placed in the bottle serves to flush out latex from the collecting tube. The water can be dispensed with when collecting latex for total solids determination. The latex will keep in a refrigerator for several months without coagulating or decomposing.

During the collecting operation we found that sores developed when the

TABLE II

S. biloculare LATEX—GENERAL CHARACTERISTICS

Consistency	Quite viscous
Color	Milky
Odor	None
Reaction	Acid—pH 6
Particle size—smaller and more uniform than Hevea	
Dispersion in water	Rapid
Brownian movement	Not discernible
Coagulation—Not coagulated in dilute water suspensions by acids, alkalies alcohol or boiling	
Sodium hydroxide agglomerates the concentrated (50% solids) latex	
Reaction to warm-blooded animals and fish	Toxic
Antibiotic test using *Escherichia coli*, *Macrococcus pyogenes* and *Bacillus subtilis*	Negative

latex came in contact with cuts or abrasions on the hand. This agreed with Goodding's experience regarding the irritating effect of the latex on tissues.

The results of preliminary tests on *S. biloculare* latex are outlined in Table II.

Latex solids. Latex solids for analysis were obtained by evaporating the latex on a water bath to a viscous liquid and completing the drying in a vacuum desiccator. The solids are quite hygroscopic and were kept in stoppered bottles. The dry solids have a light amber color and when cold are easily powdered. About 16 cubic centimeters of undiluted latex, corresponding to approximately eight grams of solids, were collected. Analytical data on latex solids are given in Table III and the approximate composition of these solids in Table IV.

The high nitrogen fraction (Table III) gave the biuret test for protein. As is characteristic of most Euphorbiaceae, the latex of *S. biloculare* contains rubber hydrocarbon. The rubber was isolated by extracting the benzol-soluble solids with acetone to remove the resins. The acetone extracted product was transparent and elastic when first prepared but rapidly oxidized in the air to a brittle film with characteristic odor of aged rubber.

Various solvents were used to isolate and concentrate the toxic materials in the latex. It was found that volatile solvents removed resinous materials from the latex solids which were toxic to warm-blooded animals but had no effect on fish. Also water solutions of the solids contained materials that were toxic to fish but had no effect on guinea pigs. The whole latex is toxic to both warm-blooded animals and fish, since the solids exist in an emulsion which is stable in dilute water suspensions, acids or alkalies, and therefore in a good form for absorption. Propylene glycol and homogenized milk were used as emulsifying agents for physiological testing of water-insoluble solids.

Toxic Resins. The resins are separated from the dry latex solids by volatile solvents, including ethyl alcohol, ethyl ether and acetone. Ethyl alcohol is the most specific solvent for these resins. By removing non-toxic materials, oils, fats, etc., from the alcohol-soluble with petroleum ether, a concentrated

TABLE III

ANALYTICAL DATA ON LATEX SOLIDS

	%
Total solids in latex as collected	50–56
Soluble in cold ethyl alcohol	37.4
Soluble in ethyl ether	70.2
Soluble in benzol	65.5
Soluble in ethyl ether and insoluble in petroleum ether	25.0
Soluble in water	27.5
Nitrogen in total solids	1.7
Nitrogen in alcohol extract	None
Nitrogen in protein fraction	9.5
Rubber hydrocarbon	2.6
Ash	1.2
Alkaloids by Meyer's and Wagner reagents	None
Volatile alkaloids by vacuum distillation of latex	None
Alcohol-soluble latex solids	Fluoresce in ultraviolet light
Alcohol-insoluble solids	Do not fluoresce

TABLE IV

APPROXIMATE COMPOSITION OF LATEX SOLIDS

	%
Toxic resins	25
Nontoxic resins	30
Oils and fats	12
Proteins	10
Saponins	20
Rubber	2
Ash	1
	100

toxic resin product is obtained. This is a light yellow solid and its alcohol solution is yellow. The latex solids insoluble in alcohol are non-toxic to animals, i.e., all the toxic resins are soluble in alcohol. Water precipitates a permanent yellow emulsion when added to the alcohol solution of these resins. Microanalysis of the yellow resin gave

C 63.49, H 8.19, N 0.00

Repeated attempts to crystallize the resin from any of its solvents or combination of solvents were unsuccessful.

The physiological action of the toxic resins on animals is a general loss of muscular control. By intravenous injection 0.5–1.0 milligrams per pound is a lethal dose. By mouth approximately four times this amount is required. Around 25% of the latex solids consists of these toxic resins.

Isolation of Saponins (1). Experiments with the whole latex show that it is toxic to both land animals and fish. Extracting the evaporated latex solids with water gave a solution toxic to fish but non-toxic to warm-blooded animals. A concentrated form of this fish poison was obtained by water-extracting latex solids which were insoluble in ethyl ether. This product when dry was a cream-colored powder which gave the following tests for saponin:

Soluble in water, insoluble in ether, acetone benzol or petroleum ether.

Strong stable foam when shaken in dilute water solution.

Characteristic color reactions with concentrated sulfuric acid, changing from redd.sh yellow-red-yellow-green.

Stupefying action on fish in dilute water solution; 0.4 part per million of the concentrated material is fatal to five-inch gold fish in 30 minutes.

A brown flocculent precipitate was formed by hydrolysis with 5% HCl. The solution was not reducing before but was strongly reducing after hydrolysis. Chromatographed on paper with tertiary butanol, glacial acetic acid, and water in proportions of 4:1:1, and sprayed with aniline acid phthalate, the presence of glucose was indicated as a product of the hydrolysis.

The brown flocculent precipitate formed in the hydrolysis was collected on a filter and dissolved in methyl alcohol in which it was completely soluble. No crystalline product was obtainable from this or other volatile solvent solutions—indicating that an amorphous sapogenin was formed in the hydrolysis.

It may be noted here that saponin is not present in all Euphorbiaceae latices and that the latex of *Hevea Braziliensis* contains no saponin.

Fröhlich's (3) "Observation on the Munchi arrow poison", in which analysis of poisoned arrows from a battle with North Algerian natives is given, indicates many similarities between the behavior of the Munchi poison and that of *Sapium biloculare*. Many fatalities were attributed to the use of these poisoned arrows.

Conclusions

In common with many other *Sapium* species, the toxic materials in *Sapium biloculare* are located in the latex.

These toxic materials consist of an alcohol-soluble resin, which is toxic to warm-blooded animals, and a water-soluble saponin, which is poisonous to fish.

The toxic resin was isolated as a brittle amber-colored solid; the saponin as a cream-colored powder. These

products are present in the latex in the form of a stable emulsion. We were unable to prepare either in a crystalline form.

The physiological action of the toxic resin is a general loss of muscular control.

The saponin serves to stabilize the latex emulsion and to give it rapid dispersion in water. Fish are stupefied by very dilute water solutions of the saponin-carrying latex.

Latex of *Sapium biloculare* contains rubber, but the quantity is small.

The leaves of *Sapium biloculare* are non-poisonous.

Discussion

Safford (7) has shown that the properties of many of our most useful drugs were known to the aboriginal inhabitants of various regions. Tobacco, datura, Peyote cactus, cocaine and belladona were among the drug plants utilized by the Aztecs in their feasts and religious ceremonies. The application of strychnos in Amazon curare, of *Cicuta* by the Oregon tribes and of *Sapium* by the Southwest aborigines are examples of the native art, in which, according to Cheney (2), " The most poisonous species indigenous to a given area have been applied successfully by natives of distinctly separated geographical locations ".

Standley (8) records that the juice of the " Yerba de la fleche " was used by the native southwest Indians both as poison for their arrows and as a means of stupefying fish to facilitate capture of them.

It is interesting to note that our experiments with *Sapium biloculare* latex would justify these early applications. The high resin content of the latex causes it to dry to a hard smooth product with strong adhesive properties for the arrow. The severity of the arrow wound would be increased by the natural tissue-irritating effect of the latex materials as well as by the direct absorption of the toxic resin emulsions into the blood stream.

On the other hand, when the fresh chopped branches of the plant are immersed in water, the latex is readily dispersed and the fish-toxic saponins are distributed. It is a tribute to the cleverness of the native Indian that he discovered the toxic properties of the Yerba de la fleche and made practical applications of this knowledge in the hunting and fishing arts where they would be most useful to him.

Acknowledgments

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Utilization of Lichens in the Arctic and Subarctic

The principal economic importance of lichens lies in their providing sustenance for hundreds of thousands of reindeer in circumpolar regions, animals upon which the Eskimos, Lapps and other Far North peoples depend for food and clothing. Industrially many of them still furnish raw materials for the dyeing and cosmetic industries, and in past times some of them served for brewing, distilling and medicine. During World War II, the reindeer industry contributed substantially to the Soviet war effort.

GEORGE A. LLANO[1]

Utilization and Related Factors

The growth of human cultures in the temperate, subtropical and tropical regions of the world has been proportionate to man's success in appropriating and improving on the innumerable species of flowering plants associated with his environment, aided by generally favorable climatic conditions and tillable soils. In contrast, the Arctic and Subarctic offer a smaller, but not infrequently luxuriant, native flora of vascular plants, lacking in agricultural significance, and an abundance of non-vascular plants. To a great degree the vegetation reflects the limitations of the environment, best emphasized in the monotonous composition of the arctic coastal flora. Low winter temperatures, a short growing period, low rate of precipitation, relatively high rate of evaporation, and the acidity of soils brought about by both climate and unfavorable microbiological development also present special deterrents to a normal expansion of agriculture. The presence of permafrost combined with low relief so impedes surface drainage that, in spite of the low precipitation, great areas of the coastal tundra are covered with shallow lakes or ponds which overflow their banks at the high-water period; here the preponderant plant forms are bryophytes and grass- or rush-like herbs. Elsewhere the damming of water by massive growths of *Sphagnum* produces a similar aqueous condition with a relative dearth of turf lichens. Nevertheless, the generally arid nature of the Arctic and Subarctic favors the increase of lichens which, in many instances, are the dominant ecological forms. As such, the lichens offer better possibilities for forage plants in enormous areas absolutely useless for other purposes.

The northern submarginal lands have never supported more than a comparatively sparse, nomadic, native population, and this has been composed of hunters or herdsmen indirectly dependent for partial survival upon the cryptogamic elements of the sea and land flora. The terrestrial vegetation of the Arctic and Subarctic can support large numbers of wild herbivores, of which the reindeer genus, *Rangifer*, has the widest circumpolar distribution. Seton has stated, in regard to the great herds of caribou, that their numbers have never equaled the available food supply.

The symbiotic relationship between Asiatic man and the gregarious land mammals, such as the sheep and the horse, is a consequence of the grass

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steppes; reindeer domestication is a contribution of the Old World arctic and subarctic lichen steppes. It is a culture which still persists across northern Eurasia and south to 50° N. latitude. In the high mountain pastures of Tuva Oblast, Central Asia, the yak, the camel and the reindeer compete with the horse as local beasts of burden. Prior to the introduction of reindeer into the New World, the innumerable herds of caribou which moved north and south of the Arctic Circle in northern America were the cornerstone of the economy of both Eskimo and Indians. After 1892, when reindeer stock was brought into Alaska for the support of the Eskimo, and until the late 1930's, when it was estimated that their numbers had increased to about 700,000 head, the culture of reindeer extended almost continuously around the polar regions. Lacking adequate means for transporting livestock overland from the southern steppes through the Siberian taiga wilderness to arctic settlements, the Soviets have been forced to look more practically upon their far northern reindeer holdings. Since the late 1930's they have applied scientific methods of selective breeding and have experimented with range management techniques for the increase of their herds and the improvement of pastures. The Soviets recognize reindeer husbandry as necessary in the economic development of the arctic regions and fundamental to the livelihood of the natives of the northern U.S.S.R. It is the only branch of stock raising that can utilize the non-grassy ranges.

The genus *Rangifer* is characterized by strong migratory habits. Although the forces which impel these movements, covering hundreds of miles, are not completely understood, they include the tormenting attacks of insects, weather conditions and other factors which urge the herds to new pastures. This apparently aimless wandering resolves itself into two distinct phases, the summer and the winter feeding periods, with an interval during which calving takes place. Through domestication, these phases of the migratory cycle are inhibited in reindeer "stock" to a milder expression of movement. Whether reindeer husbandry adheres to close herding practices or to the newer permanent ranching basis, it still must have access to enough grazing land to supply the desired seasonal fodder, which cannot be cultivated nor harvested to meet known forage needs. Although in summer, reindeer feed and fatten on grasses, sedges and variable amounts of herbage which they supplement to a considerable extent by browsing on the tender portions of willows, birch, and shrubs, lichens may also be eaten, when moist. Indeed, in the fall and throughout the winter the animals exhibit a marked preference for lichens. Since this period comprises the greater part of the year, the extent, quality and quantity of the lichen pastures are of paramount importance. Data based on stomach analysis and field observations show considerable variance, depending on the composition of the pastures and restrictive weather conditions. Thus on Novaya Zemlya, where heavy snows make lichen ranges inaccessible, reindeer are able to subsist on dried summer plants and browse. Under similar conditions on Nunivak Island in the Bering Sea, a semi-domesticated reindeer herd has been severely reduced by starvation. In Fennoscandia, when icing or "flen" conditions prevail, the Lapp herders move their animals into ice-free pastures or into the forest where they may feed on tree-growing lichens, often eating the bark of *Betula*. On the Malozemel'skaya Tundra, the amounts of lichens found in the rumen of reindeer reportedly range from 30 to 40 percent of all food taken. During the summer and autumn lichens amount to from 25 to 30 percent of the total food of fawns, whereas adult rein-

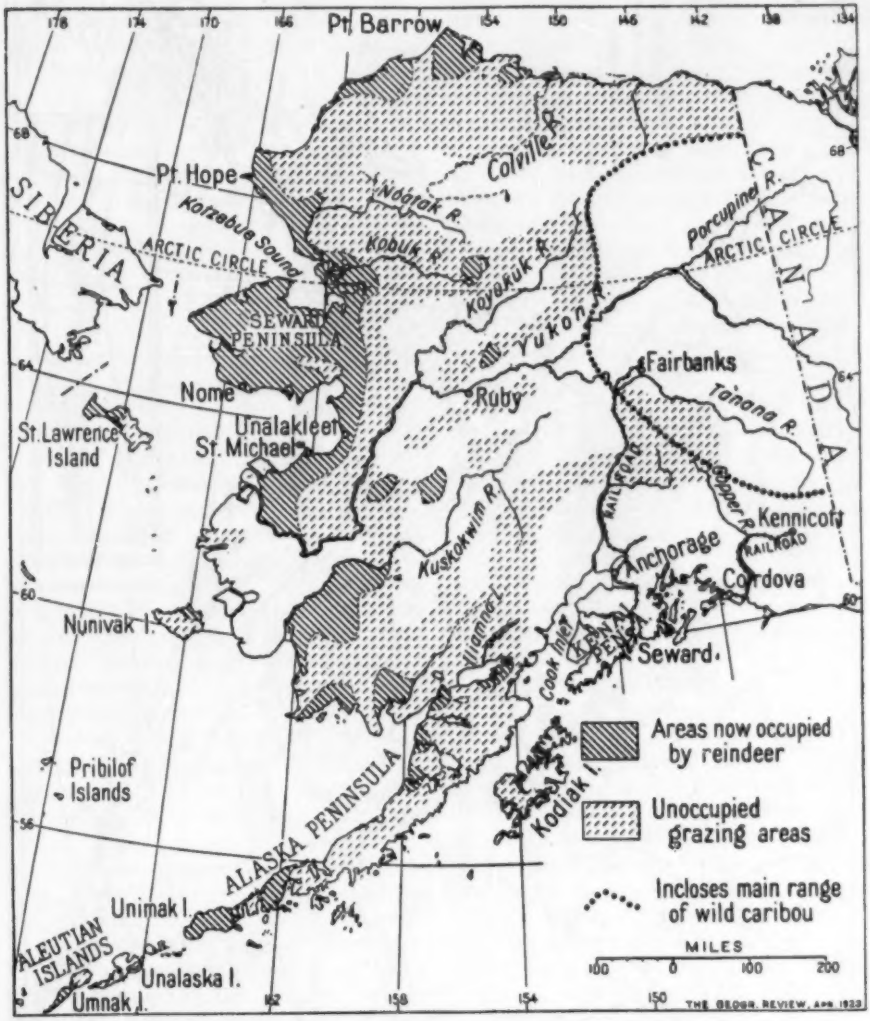


FIG. 1. Distribution of reindeer grazing in Alaska and reindeer ranges occupied in 1922, according to Seymour Hadwen and L. J. Palmer. The present distribution includes the area from the Noatak River south to St. Michael and inland to about the 158th meridian; and the islands: St. Lawrence, Nunivak, the Pribilof's, Atka, Umnak and Kodiak. (After M. F. Lantis).

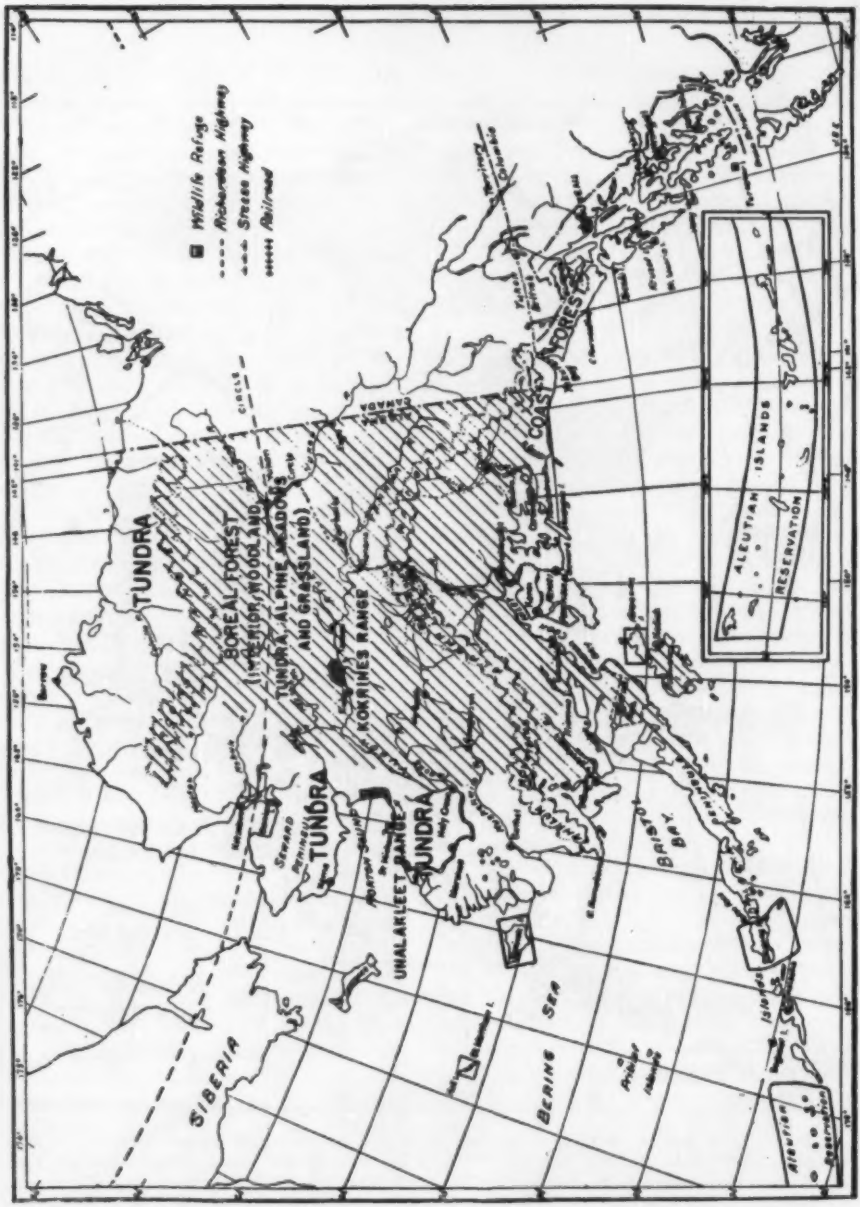


FIG. 2. Distribution of Alaskan vegetative type cover in general and approximate relationship of the tundra to the boreal forest. The De Long and Baird Mountains extend from the Brooks Range east along the Noatak and Kobuk Rivers almost to the coast. Forest cover reaches within about 25 miles of tidewater around Kotzebue; in the region of Norton Bay, the spruce comes to the water's edge. (After L. J. Palmer and Charles H. Rouse).

deer average about 25 percent lichens and from 35 to 40 percent *Salix* and *Betula* browse during autumn. According to Soviet research, lichens constitute 70 to 75 percent of the annual reindeer ration.

Reproductive potentialities of domesticated reindeer have proved to be high; estimates of the theoretical population that can be carried on circumpolar grazing lands have been given as high as 100,000,000. However, reindeer increases, even with progressive government assistance, have failed to achieve anything near the theoretical maximum. G. J. Lomen predicted, in 1920, that by 1950 Alaska would have about 10,000,000 head of reindeer. In 1950, Lantis found that the Alaskan herds were reduced to less than 28,000 head. Two years later, the Tom Brower herd, the last on the Arctic Slope, was reported (correspondence) destroyed. Reindeer husbandry is beset by many overlapping and interplaying factors which, if disregarded, will reflect the highly speculative aspects of any individual undertaking. These include the decimating effects of predators, insects, disease and weather; the willingness and adaptability of Eskimos to accept a new mode of livelihood, necessitating skills in herding and range management, and the problem of finding market outlets for meat, hides and furs. Reindeer management, like every other form of land-cropping, is applied ecology. Therefore proper evaluation of the vegetational units for determining the carrying capacity of a range is necessary for the successful application of range management techniques, details of which are partly available from published floristic, ecological and phytosociological studies of some circumpolar areas. This report concerns only those factors that influence the lichen ranges.

General Character of Range Lands

The circumboreal distribution of the latent northern pastures extends, except in Alaska and Greenland, partly below the tree-line. For the purposes of this study, these are referred to as tundra and taiga ranges. In both ranges lichens are a manifest part of the vegetation and the principal forage of domesticated reindeer, caribou, muskox, and, in varying degrees, of other wild herbivores. Not all lichen species, however, are suitable food, and the unequal distribution of the desirable ones, in both species and quantity, is an important factor in successful range management. The union of tundra and taiga has an economic significance for arctic range management practices that cannot be disregarded. It marks a transitional zone, variously described as wooded tundra or lichen woodlands, in which the lichen flora attains maximum development from both trees and shrubs and over the ground. In addition to supplying either grazing or browsing pasturage, trees give protection from the force of winter storms which otherwise keep the herds in constant movement. Consequently the wooded tundra is ideal winter range for reindeer and caribou.

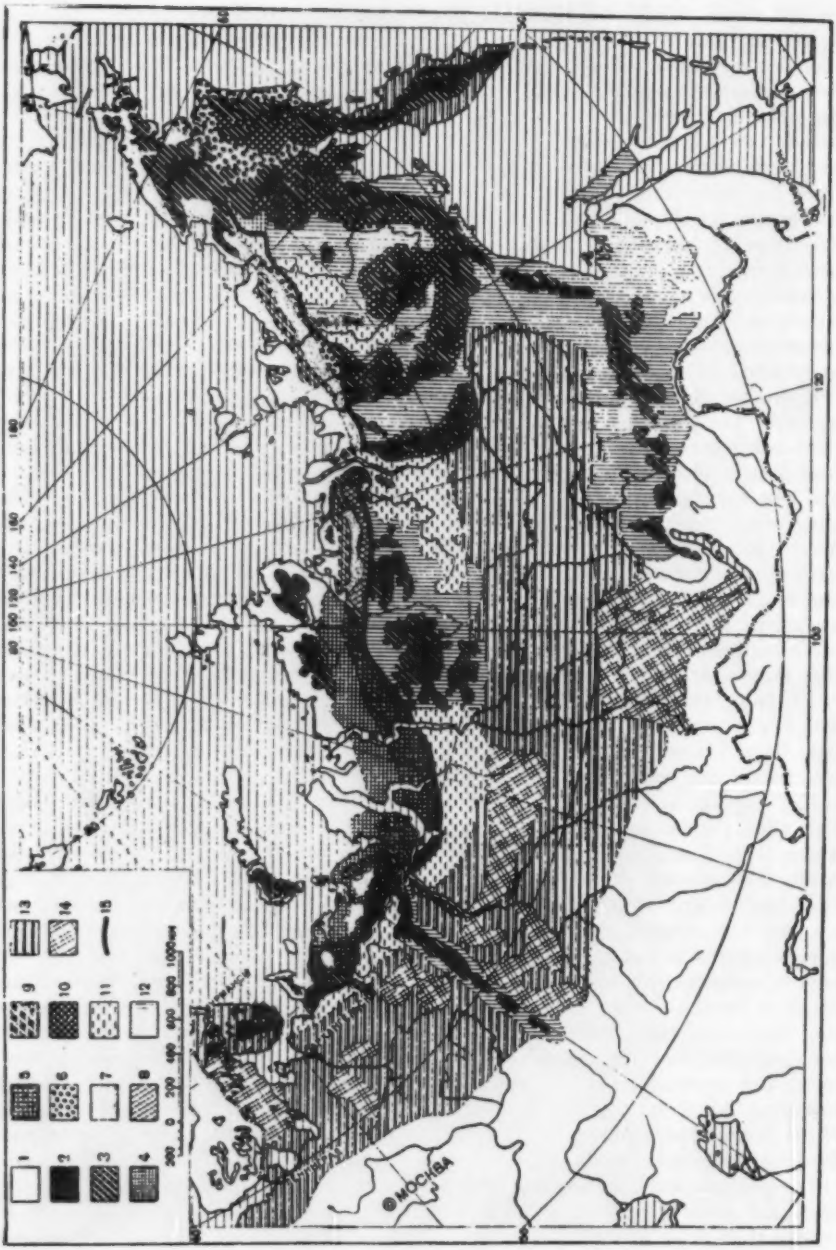
In Alaska the Brooks Range forms a barrier of such breadth that it restricts grazing to the tundra ranges north of the Arctic Circle. The importance of this orographic feature to the practice of reindeer husbandry on the Arctic Slope of Alaska has not been clearly realized, despite the common knowledge that at the end of summer unconfined caribou migrate through mountain passes and southward below the tree-line. For the most part the North Slope, in addition to being exposed, provides indifferent pasturage. In comparison with the lichen fields of Finnmark, Norway or parts of the Barren Grounds of Canada, lichen cover over the Alaskan tundra is poor. The low tundra along the coast is, in part, marshy and supports a rich sedge-grass association. Even mosses are more abundant than lichens on the polygonal soils rising above the spring water-mark.

FIG. 3. Aerial photograph of a ridge at an altitude of about 4,000 feet on the North Slope of the Brooks Range in Alaska, showing a herd of approximately 300 caribou resting on the upper part of a late-spring snowbank. To the left of the snowbank, lichen growth is evidenced by a darker hue of the rock surface. A fine pattern of undulating lines (visible in a photo print) to the left of the snow along the lower slope radiates from the trampled area of the snowbank toward the larger patches of lichens. Some of these lines do not indicate grazing trails but, undoubtedly, the effects of frost and related ground-pattern phenomena. However, the well-marked trail (upper left to center) along the ridge suggests that this slope has been used repeatedly in previous seasons. The tundra in the background is typical of the area and at this time of year has an abundance of succulent herbage and water. (U. S. Navy Photo).

On the whole, lichens constitute the less significant part of the vegetation. Although they are more apparent on the drier, interior uplands, lichens are not the dominant plant form, except in the broader river bottoms where they occur as lichen heaths. Lichens are absent from the water-flushed meadows along the gentle foreslopes of the mountains. The steeper slopes, being very dry, appear barren, but, in reality, the scree has a considerable amount of lichen herbage, which, appearing as a dark cast over the mountain slopes, sets off the stable talus in contrast to the light-colored streaks and patches of loosened rocks and shifting soil. The dominant lichens are *Alectoria ochroleuca* and several species of *Umbilicaria*, although *Cladonia*, *Cetraria* and *Parmelia* grow in small pockets of loose soil caught between the rocks. After the snow disappears, low cloud banks provide the only moisture. Caribou find these mountainous lichen-slopes attractive, even though there is more succulent feed in the valleys. It may be that they seek out the higher slopes for relief from the plague of mosquitoes, which are active throughout the long light days. However that may be, caribou would not remain at this altitude unless they had access to food and water. Late snow patches are the only source of water. In brief, the pastures of the Arctic Slope are more favorable for summer than for winter grazing. Close herding and the resulting concentration of domesticated reindeer in delimited areas have repeatedly depleted the local ranges, which at best have a low carrying capacity. Even with the amenities of modern transportation and communications systems, the inaccessibility of the taiga wintering ranges on the southern slopes of the Brooks Mountains is still a serious hurdle to large-scale reindeer husbandry.

The pastures of the Canadian Northlands are more diversified and more extensive than those of the Arctic Slope of Alaska. If past records on the prevalence of caribou are any criterion of grazing values, the carrying capacity of the Canadian ranges must be rated high. According to Banfield (in Polar Record, 1952), the barren-ground caribou have a normal summer range of 300,000 square miles and a normal winter range of 295,000 square miles; Brooks' estimate of the Alaskan ranges is 150,000 square miles. The potential of the Canadian ranges, however, depends not only on area but also on the accessibility of the tundra and barrens to the taiga. The extensive, close-growing ground cover of lichens rich in the *Cladonia* species found in the shelter of the wooded tundra and along the riverine forests is undoubtedly a most significant and uniform feature of the north Canadian pastures. The additional bounty of arboreal, pendulous lichens, such as *Alectoria*, *Evernia* and *Usnea*, is an auxiliary source of feed which is eaten by deer, reindeer, caribou and moose when ice over the snow prevents grazing. In this respect Banfield's observation that caribou generally move at right angles to the nearest tree-line may well suggest that the special food and protection of this area is an attractive force, even during migration.

The arctic lands of Eurasia have been partially reported on by a series of expeditions studying means of expanding the reindeer industry. Through air photography, air observation and ground spot checks, about 80 percent of the region west of the Yenisey and east of the Yakut A.S.S.R., including Kamchatka, has been mapped on 1:100,000 sheets. According to officials of the Soviet Arctic Museum, the total number of reindeer in the U.S.S.R. today is about 2,500,000. Earlier botanical investigations estimated that the Far North pastures had a potential carrying capacity of 10,000,000 reindeer. The Far North includes both developed and undeveloped reindeer areas; the region lies north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of a line extending in a northwesterly direction from 140° E. longitude, 50° N. latitude and running south of Yeniseysk and Surgut to Arkhangel'sk on the White Sea. Investigations are now being carried out in the more southern portions of the Far North.

The orographical variety of the north Asiatic hinterland and the northward penetration of riverine forests make for a greater discontinuity of vegetational boundaries than in North America. The tundra zone along the Siberian coast is narrowest in the west, where it contacts the "wet taiga" of evergreen conifers, increasing in width eastward across the West Siberian Plain and then merging into the uplands and highlands of the Chukchi Peninsula. The terrain along this zone is not unlike that encountered on the Arctic Slope of Alaska. In the west the tundra merges into spruce and pine forests, rarely larch; in eastern Siberia it adjoins a "dry taiga" of deciduous coniferous forest. Intervening summits of higher lands assume tundra or mountain-meadow characteristics. The transition between tundra and taiga is a normal feature of the landscape in which lichens are a common component of the flora and the unit for computing carrying capacity.

In Yakutia grazing areas are divided into 24 associated vegetational types. The yearly yield of lichen fodder in this region is reckoned at 3.7 million tons with a basic total potential of 55 million tons; herbs and shrubs are estimated at 13 million tons. The Taymyr Peninsula is described as 75 percent tundra, 25 percent forest, and adequate only in summer pastures. The Anadyr' region is classified as having 11 principal types, and sufficient in summer and winter pastures. However, full utilization of these pastures is severely restricted by topographical features disadvantageous to herding, by the local disproportionate ratio between summer and winter pastures, and by the existence of negative areas, such as uplands of frost-shattered rocks and bare stone ridges which support an indifferent herbaceous vegetation and an equally thin cover of lichens, primarily of the smaller rock species. In the Soviet Far East the herbaceous fodder is said to be deficient so that, even though the lichen vegetation is adequate, it may serve to limit reindeer husbandry. An analysis of the principal lichen formations and their distribution in the U.S.S.R. by V. S. Govoruhin of the Glavsevmorput' (Main Administration of the Northern Sea Route) is presented in Figure 4.

The high concentration of reindeer breeding in northern Europe is indicative of the value of good grazing lands in close proximity to ready markets. The winter ranges, the principal feature of the region, consist of open pine and spruce forests with a luxuriant understory of *Cladonia* species transitional to the narrow coastal tundra and the taiga

FIG. 4. A schematic map of the geographical distribution of the important lichen formations of the tundra, wooded tundra and various taiga of the northern U.S.S.R. (After Kursanov and D'yachkov).

1. Lowlands without reindeer lichens.
2. Bare or only crustaceous lichens.
3. Mountain tundra lichens.
4. Mossy-lichen *Cladonia* tundras.
5. Fruticose *Cladonia* tundras.
6. Boggy hills with *Cladonia* tundra.
7. *Cetraria* tundra.
8. *Cladonia* and *Cetraria* associated with shrub-tundra.
9. *Alectoria* tundra.
10. *Alectoria* mountain-tundra with "kedr" [*Pinus cembra*] on slate or schist.
11. Plains with sparse forests and Iceland moss [lichen].
12. Mountainous with sparse forests and denser forests with Iceland moss [lichen].
13. Plains taiga.
14. Massifs of pine forests with reindeer lichen.
15. Tree-line.

of the interior plains. To the west, on the Kola Peninsula, pine largely replaces spruce, but in the Petsamo area spruce fronts the coastal tundra interrupted by the naked rock of low tunturis (bald mountains). In Scandinavia birch succeeds pine and marks the timberline of the low subalpine zone. About 20% of the Kola region is covered with carpets of lichens; west of the Kirov Railroad the reserves of lichens are calculated at 600,000 tons of dry material. On the Scandinavian Peninsula, as in the Tuva region, the broad mountain pastures above timberline are used for summer grazing by both the tame (porro) and wild (peura) reindeer. (See Fig. 5).

In the reindeer husbandry of northern Europe, especially in Scandinavia, there is strong competition for the limited grazing lands. This is partly because of the pressure exerted by agricultural and forestry interests, the increased urbanization brought about by mining developments and the effects of political boundaries. The closing of Russian pastures which were formerly available to Finnish herders has aggravated the grazing problem and has resulted in overcongestion of the remaining tracts. The Swedish government has long realized the intrinsic value of reindeer culture for the independent maintenance of the Lapps and has tried to comply with the hereditary needs of the Lapp herders. In the case of Lapp reindeer movements across the Swedish-Norwegian borders, the differences have been the subject of international arbitration. Thus the use of the Norwegian fjell lichen pastures, which are essential to Swedish Lapp herding, is controlled by regulations invoked jointly by the two governments. These define the routes to be followed, the time for grazing, the number of reindeer allotted per area, the time of entrance and compensation for damage. One cause of contention has been the damage in areas where lichens are hand-harvested as fodder for farm animals. The lichen fields of Finnmark represent the best type of lichen pasturage available, reflecting the rotational use of the land and careful analysis of its carrying capacity.

Morphology and Reproduction of Lichens

Lichens bear so little resemblance to the more common forms of vegetation that it is difficult to convey a conception of their unique structure to the layman. Consequently they are frequently considered to be a kind of moss. Moreover, those species which are important to reindeer management have been, unfortunately, called " reindeer moss ", which is a source of added confusion. The term, as generally applied, covers numerous species, and to give meaning to the art of reindeer land management, it is important that they be identified as to species or at least as to genera.

Lichen structure lacks stems, leaves, roots, flowers and true seeds; it is a specialized non-cellular system of irregular limitations that is correctly described as a " thallus ". Lichenologists have classified thallus forms into three types. The crustaceous lichen thallus is usually of small size, frequently lacking an observable thallus, often closely adhering to bark, soil and rocks; its small size and habit minimize its value as a grazing plant. The foliose or leafy lichen thallus may grow to six or more inches in diameter, forming irregular succulent structures over the substrate. The erect or hanging, more or less cylindrical, thallus forms may develop on the ground or from trees and rocks, and are described as fruticose or filamentous types. The grazing value of northern pastures in winter is primarily a result of the compact growth of fruticose lichens on the ground and of the arboreal habit of the filamentous species.

Microscopically, the internal anatomy of lichens differs markedly from all other forms of plant life. It consists of a

FIG. 5. Reindeer grazing areas in northern Sweden and Norway. (After W. B. Wiklund).

tightly woven web of fungal threads, or hyphae, through which innumerable bright-green, yellow-green or blue-green algal cells may be scattered or oriented. It is the presence of algae in lichens that partly gives them their dominant coloring, although when dry some may appear nondescript. The symbiotic relationship exhibited by this dual organism is dependent upon the specialized and apparently balanced functions carried out by each partner. The chlorophyll-bearing algae can synthesize sugars and a special form of carbohydrate, lichenin, which can be used by the fungus for its own growth; the algae would be easily desiccated but for the water-absorbing and retaining powers of the endless hollow hyphal threads of the fungal partner. As a result of this mutual metabolism, lichens can achieve success under very dry conditions or extremes of temperature and can sponge up moisture from the lightest mist. The methods of reproduction of lichens give a better understanding of the relationship of the algae and fungus. Lichens may reproduce by fragmentation, that is, a broken part of the thallus may, under suitable conditions, reproduce itself; or they may develop spherical bodies (soredia) containing fungal threads surrrounding a few algal cells, which are liberated as a powdery mass easily distributed by the wind. Lastly, the fungal part may form spores in specialized closed perithecial or open apothecial structures after the usual manner of fungi without participation of the algal associates until after the spore germinates. It is because of this method of sexual reproduction and the fact that the fungus enmeshes the algae that the former is considered to be the dominant participant. The ability of these organisms to reproduce themselves as a unit with specific, morphological, taxonomic, ecologic and physiological properties makes it convenient to treat them as homogeneous units comparable to true mosses, hepatics, fungi and algae.

Lichens are perennial plants of proverbially slow growth. According to Stocker, intensity of photosynthesis in lichens is only one-fifth or one-tenth of that in cultivated plants. Although insignificant in size, the lichens are important as forage plants partly because of their massive accumulation under special conditions. Their activity is dependent upon available atmospheric moisture, even in the form of mist or inorganic substances as dust or solutes in surface waters. Under certain microclimatic conditions, lichens are active even at low temperatures, particularly under a thin snow cover, their vegetative period being thus extended into early spring and late autumn. They attain their best development on the southern exposure of mountains, under thin forest cover and on the scattered trees. On low tundra their best development is seriously retarded by flooding, by wind and wind-driven snow and by competition from the grass-sedge association.

Foliose species grow peripherally; the primary growing portion may persist or be partially decomposed. Fruticose forms grow apically, with continuous decomposition of the basal portion in the case of terrestrial species; in a sense they possess the power of unlimited growth, although they rarely exceed eight inches in height. The cushion formation of certain fruticose groups, like Cetrariae, Cladoniae and *Thamnolia*, on forest soils or open terrain, is best observed in northern or alpine regions; such cushion-like formations are often induced by wind action, the plants there being less sensitive not only to wind but to variations of temperature and intense insolation. The viable part of the fruticose forms is the upper half or third of the plant, and it is from this portion that regeneration proceeds.

Growth and Ecesis

In determining the carrying capacity of any type of range, exact knowledge of the annual growth of lichens is basic to a proper estimation of the available winter fodder. Although there are on record scattered casual observations on the growth of lichens, few are of sufficient exactness for computing yearly or average growth rates for any one species in any given latitude. General estimates, based on common knowledge of past grazing experience in various parts of the Arctic and Subarctic, are available. It has been shown that fruticose lichens, trimmed to a depth of one to two centimeters, quickly recover; cutting to five centimeters is more detrimental to recovery. Moderate feeding by reindeer, that is, light cropping, permits recovery in from four to five years. This recovery is quicker on young lightly-cropped lichen stands than on the more mature, thick, cushion stands, which may often be cropped down to the inactive basal portion. In judging the range condition of any previously pastured area, it is well to consider that complete recovery may not be desirable, since it would involve forage loss through excessive basal decomposition. In brief, moderate pasturing with a short interval of rotation may be more advantageous than prolonged abandonment. Successful lichen range-management is thus largely dependent upon the herder's ability to evaluate the cropped lichen stand in terms of serviceable recovery.

Lichens when dry are exceedingly brittle, although they never become completely desiccated. Use of lichen pastures in dry periods either for grazing or for migratory purposes results in excessive fragmentation of the thalli and serious loss of pasturage. This is further aggravated during the insect season, when the animals are accustomed to make short rapid runs into the wind to shake off their tormentors. Under optimum conditions of range use, that is, when the lichen stands are moist or covered with a protective blanket of snow, there is undoubtedly a normal amount of fragmentation, which is an important factor in the regeneration of new individuals. The duration and intensity of grazing in areas of mixed sedge-grass and lichen forage accompanied by excessive trampling may result in total replacement of the lichen association by gramineous plants. Trampling of lichens is thus a major factor in estimating available pasturage.

Damage to lichen stands may be brought about also through the destructive activity of rodents, which during years of peak cycles may be present in excessive numbers, competing directly or indirectly by using lichens for food or by destroying them in their burrowing activities. Such rodents as *Lemmus*, *Dicrostonyx*, *Clethrionomys*, *Arvicola*, *Microtus* and *Lepus* have reportedly exerted a detrimental influence on the lichen pasturage of the Bol'shezemel'skaya Tundra ("great land tundra") and the Malozemel'skaya Tundra ("little land tundra") of north European Russia. A similar phenomenon was observed by the author in June of 1949 around Wainwright and Point Barrow after a period of high lemming density. In many places the sedges were closely cropped, and sedge and lichen detritus were washed into windrows by the thawing snow.

Fire, particularly destructive to dry lichen fields, may result in total loss of available pasturage for many years. The effects of fire on reindeer pastures in Alaska have been most noticeable in the northwest mining district. Lacunae, or gaps, in the lichen vegetation in Norway resulting from fires dating back 50 or more years can be readily traced by comparison of the original lichen cover with the subsequent adventitious and

often less desirable species, including mosses, which may be absent from or have limited distribution in the older flora. Through negligent practices on the part of the Uryankhay and Soyots of the Altay and Sayan regions, where grasslands for summer feeding are critical, about 13% of the Tuvinian forest is yearly destroyed by fire.

Composition and Interspersion of Lichens

In appraising the comparative worth of winter pastures, the seasonal need with a possible alternative is the main prerequisite. With this must be considered the quality and quantity of the growing feed available, the composition of the flora, the stability of the pastures to herding, regrowth rates, and the distribution of the plant species. The quantity of lichen feed available is not determinable by the total number of lichen species which may be recorded as composing the flora of a given region. The lichen flora of circumpolar areas may vary from 300 to 700 species in about 100 genera. Some of these may be locally abundant, others rare; many are relatively unimportant because of their small size or their development in inaccessible places. The lichens important in the composition of reindeer ranges number about 50 species in 20 genera, of which 15 species are the most desirable. The lichens most fed on by reindeer belong to the genera *Cladonia* (section *Cladina*), *Cetraria*, *Sphaerophorus*, *Thamnolia*, *Parmelia*, *Cornicularia*, *Evernia*, *Duforea*, *Umbilicaria*, *Alectoria* and *Usnea*.

Of the terrestrial lichens the Cladoniae are, economically, the most important because of their size, their wide-branching structure, their close-growing habit and wide distribution in circumpolar lands. Of the innumerable species described, the Cladina group—*Cladonia alpestris*, *Cl. mitis*, *Cl. impexa*, *Cl. rangiferina* and *Cl. sylvatica*—is characterized by a strong development of the secondary thalli, or podetia, and an absence of primary thalli. Growth of the secondary thalli is apical and more or less continuous. Regeneration is, in the usual absence of apothecia, dependent upon fragmentation. The species grow singly or intermixed in cushions or carpet-like mats extending over many miles. They thrive best under an open forest canopy in areas of definite snow cover and, when damp, withstand considerable trampling. They grow best over glacial drift and compete well with, and even prevent the normal development of, vascular plant seedlings. Although they have wide habitat capabilities, Cladoniae show slow recovery after fire.

Cladonia alpestris is the most valuable species; *Cl. mitis* is a close second; and both are found in the more northern ranges. *Cl. sylvatica* is more southern in distribution. *Cl. rangiferina* has a general distribution and usually grows among other species of Cladina. *Cl. amaurocraea*, *Cl. gracilis*, *Cl. uncialis*, *Cl. verticillata* and others are also eaten by reindeer but generally lack the compact habit so valuable for forage plants.

Below the living stratum the undecayed old growth of Cladina species forms layers of "white" peat, representing the accumulation of centuries. The slow decomposition of lichens *in situ* is due not entirely to the normal effects of arctic temperature and slow biological processes but also to the presence of chemical substances, lichen acids, which themselves forestall the action of saprophytic microorganisms in the soil.

The Cetrariae are equally important, since they fulfill the quantitative requirement essential for forage plants. Although their primary thalli never attain the podetial size attained by the Cladoniae, nor the compact habit of the Cladina group, they exhibit considerable

tolerance to extreme habitats. *Cetraria hiascens* (*delisei*) is frequently found in the shallow pools of cold bogs and other wet areas; *C. cucullata* and *C. nivalis* in pure stands or intermixed with other plants, especially on slopes irrigated by melt water from higher snowbanks. *Cetraria islandica* and *C. crispa* have a general distribution throughout the Arctic but attain maximum development in dry mountain areas. All of these species are of proven range value.

The terrestrial species of Alectoria—*A. ochroleuca, A. nitidula, A. nigricans* and *A. nidulifera*—are locally dominant forms on tundra and upland heaths. These thread-like lichens are usually intertwined among other lichens but may occasionally form small scattered cushions. *Alectoria ochroleuca* is of primary value in those areas where it forms extensive fields important for grazing. Govoruhin's "*Alectoria* tundra" (Fig. 4) refers to this species. In Alaska it was seen by the author more often in the uplands, especially in the mountain passes, where it grew over morainal and talus detritus almost to the exclusion of other lichen species.

The dark-colored Alectoriae and light-colored Usneaceae are important lichens of the circumboreal forest zone, but are more conspicuous in coniferous than in broad-leaved forests. Both members grow in great profusion, pendant from branches of trees and shrubs; these are normally torn loose by wind and carried to other trees so that they are more commonly noted in open forests or forest margins than in the dense taiga. Almost all the forest herbivores feed on these arboreal species, and in time of deep snow or when ice prevents access to terrestrial lichens, reindeer and caribou depend on them for winter food.

The *Stereocaulon* species usually occur on gravels or rock, in scattered patches and more or less interspersed with other lichen species. On the Chukchi ranges they constitute the basic species of lichen and there cover vast areas.

Sphaerophorus, Thamnolia, Cornicularia and, to a more limited extent, *Duforea* are terrestrial arctic forms with short, erect, fruticose thalli. Although these genera never attain the compact habit, they are common units throughout the circumpolar regions.

The foliose forms of *Cetraria* together with *Parmelia, Peltigera* and *Nephroma* are ubiquitous northern lichens with flat spreading thalli. *Peltigera* is common over soil, while *Parmelia* occurs over both rocks and soils. Species of the latter often adhere close to the substrate, but it has been observed that reindeer will lick them off. The peltate *Umbilicaria* are found only on igneous and metamorphic rocks, and, though generally small in size, often occur in such great numbers that they darken the mountain slopes.

The lichen diet of reindeer—and this holds true of other food eaten by other game animals—may follow a more or less definite sequence. The lichen species eaten may depend upon their relative abundance or availability, or their order of palatability, with the possibility that seasonal changes and physiological needs may be underlying criteria. If the staple lichen or other normal fodder is exhausted, reindeer are known to fill up or gorge on plants for which they normally show little propensity, as, for example, the non-nutritive mosses. In Alaska *Nephroma arcticum*, a common circumpolar lichen, has been cited as a reindeer lichen; the Lapp herders of Scandinavia, who have evolved a rich vocabulary of Lapponian terms for lichens used by reindeer and who clearly differentiate between true mosses and lichens, state that *Nephroma* is never eaten or is eaten only in the absence of other foods. Lichens and snow are the primary sources of food and water for reindeer, caribou and muskox during the

long critical winter period; it appears, then, that lichens may provide these animals with their vitamin and mineral needs.

Lichen Components and Biochemistry

The nutritive value of lichen fodder lies in substances which are synthesized in the thallus and which may vary in quantity among different species and in one and the same species with dissimilar habitat backgrounds. The principal substance is the carbohydrate, lichenin; proteins (0.5 to 3%) and fats (1 to 2%) are present in insignificant quantity. The majority of lichens are very poor in minerals, with an ash content that rarely exceeds two percent of their dry weight.

The important foodstuff that composes the greater part of the thallus is held as reserve carbohydrates, cellulose-like polysaccharides of the hexose type sometimes described as polyglucides, of which lichenin is the most prevalent form. Isolichenin, a starch-like polysaccharide, occurs along with lichenin and differs from it only in being soluble in cold water, in staining blue with iodine, and in yielding maltose in enzymatic hydrolysis. Lichenin is soluble in hot water, giving a colloidal solution, and is easily hydrolized to yield D-glucose. Cellulose is less common in lichens, but in the Cladoniae it amounts to from six to ten percent of the dry weight of the plant; this is water-insoluble and less readily hydrolized than lichenin. Some lichen species are characterized by more specialized forms of soluble carbohydrates; all possess the common property of yielding glucose when treated with dilute acids. Thus pustulin replaces lichenin in *Umbilicaria* which, unlike most lichens, requires an external source of organic matter. Peltigerin is common to the Peltigeraceae, while zeorin occurs in *Anaptychia*, *Peltigera* and *Nephroma*. Simple reducing sugars are rare in lichens; erythritol and mannitol have been reported in considerable amounts in a few tropical species. Through the action of aerobic and anaerobic bacteria of the digestive system primarily, and not of enzymes, the polyglucides are hydrolized into simple sugars. Lichenin and inulin, thought to be peculiar to lichens, are present also in some of the higher plants. The former has been isolated from oats, while the latter occurs in chicory root, dahlia bulbs, dandelion roots, sweet potatoes and Jerusalem artichokes. D'yachkov and Kursanov have reported that the total carbohydrate content in *Cetraria nivalis*, *C. islandica*, *Cladonia alpestris*, *Cl. mitis*, *Cl. deformis* and *Alectoria ochroleuca* constitutes from 80 to 85% of the dry weight of the plant. In *Peltigera* and *Stereocaulon paschale* it is from 48 to 72%. A marked contrast was noted in the formation of lichenin, which in *C. islandica*, *C. nivalis* and *A. ochroleuca* made up from 45 to 50% of the water-soluble carbohydrates; in the rest of the lichens tested it amounted to less than 5%. The residue of the carbohydrates was in the form of water-insoluble hemicelluloses and celluloses and pentosans. *C. islandica* and *C. nivalis* differed physiologically in human digestibility tests; in the former from 45 to 50% of the lichenin was digestible, while the latter provoked intestinal disturbances which necessitated termination of the experiments. White mice have been reported to utilize about 70% of available lichenin.

The bright coloring and bitter taste of many lichen species are in part due to the effects of organic acids of the phenol type which may form crystals in the thallus. The chemical structure of the 200-odd lichen acids which have been described reveals a unique pattern unknown in other plants, and is presumed to result from the symbiotic metabolism of alga and fungus but primarily of the fungus. Some of these acids are specific to species, but most are common to

groups, while some species may have more than one lichen acid. The amount of the acid varies from two to three percent to as much as 25% in some of the economically important dye lichens. Lichen acids are of taxonomic value in differentiating certain species or in relating larger groups; the distinctive bitter taste characteristic of certain of these acids is also used to identify some species.

The physiological effect of lichen acids on the feeding habits of wild herbivores does not appear to be harmful, although it may serve to determine predilection for certain lichen species. At least two species are reported as poisonous and have been used in the control of wolves. *Evernia* (*Letharia*) *vulpina*, containing vulpinic acid, and *Cetraria pinastri*, containing pinastrinic acid, are both bright-yellow species with wide circumboreal distribution. That the former lichen is not deleterious to herbivores has been brought out in field observations by William Q. Douglas, who noted some 50 elk feeding on *E. vulpina*, *A. sarmentosa* and *A. fremontii* in the mountain region of Grosse Point, Washington. R. S. Palmer (New York State Museum) has noted, in correspondence with the author, that *Usnea* is one of the best foods in baiting traps for northern white-tailed deer, that on overbrowsed ranges *Usnea* was completely cleaned out as high as the animals could obtain it, and that, when trees are being felled, tame deer will come running to feed on this lichen. On Vancouver Island, Cowan states that 15% of the annual diet of *Odocoileus hemionus columbianus* is chiefly Usneaceae. In some of these illustrations lichen feeding occurred late in the winter on over-grazed or over-browsed areas or under unfavorable climatic conditions. However, it may also indicate a nutritional deficiency or, as Palmer suggested, a physiological need for some "salt". This craving is well exemplified by reindeer which are greatly attracted to human and dog urine, and it is the custom of Eurasian hunters as well as of the Central Eskimo (Canada) to use urine and lichens as bait over snow-covered pitfalls to attract the wild reindeer.

Certain minerals have been noted in lichens which do not ordinarily occur in them. *Parmelia molliuscula* has been reported from the western United States as containing selenium in quantities sufficient to seriously affect sheep and cattle. Beryllium has been observed in *Parmelia saxatilis* and *Xanthoria parietina;* copper has been detected in other lichen species. Normal development of the bacterial flora in the colon of ruminants appears to require at least trace amounts of certain specific minerals. The need for investigating this aspect of lichen nutrition becomes more apparent in the light of the normal selectivity shown by species of *Rangifer*, the seasonal selectivity exhibited by members of the Cervidae, and the temporary adaptation of cattle to lichen fodder. Correlated with this is the generally accepted fact that different diets will produce marked and even radical differences in the intestinal flora of different species of animals.

The vitamin content of several species of fruticose and foliose lichens eaten by reindeer has been reported upon by L. J. Palmer and associates. Their findings indicated that these species yield moderately high digestibility coefficients in reindeer. The plants selected were arbitrarily divided into short-growth types on dry sites and tall-growth types on moist sites, and mixed with alfalfa and oats or as a pure diet were fed to rats. The latter would not tolerate large amounts of the tall lichens at levels greater than 10% in pure diets; the species used included *Cetraria islandica*, *C. cucullata*, *Cladonia alpestris*, *Cl. sylvestris*, *Cl. gracilis*, *Cl. amaurocraea* and *Cl. sylvatica*. A vitamin-A response was obtained from this group, although it

could not be demonstrated; vitamin-D response was superior to that shown in short-growth forms. Short-growth forms were well tolerated at the levels fed; the species included *Alectoria nigricans, A. ochroleuca, Cetraria nivalis, C. hiascens, Cladonia bellidiflora, Cl. gracilis, Lobaria linita, Stereocaulon tomentosum, Thamnolia vermicularis, Nephroma arcticum, Parmelia physodes* and *Peltigera* species. Vitamin-B complex was absent from both short- and tall-growth forms. Ergosterol has been reportedly isolated from *Peltigera canina* and *Cladonia rangiferina*, the latter, in September, showing only traces of vitamin-D.

According to Kursanov and D'yachkov, the critical deficiencies in the diet of reindeer are of proteins, fats, minerals and vitamins. They note that when forced to spend the long winter on lichen fodder, reindeer suffer from a whole series of metabolic disturbances. One of these disturbances is protein dystrophy which is the result, not only of the low protein content of lichens but also of their low digestibility. The effects of mineral deficiencies, particularly calcium, are evidenced in the generally poor condition of hooves and bones at the end of winter. And a further point may be added, namely, that, as snow-eaters, reindeer for all practical purposes drink distilled water from the freeze-up to the break-up of lakes and streams. As a result of this monotonous diet, one can understand the peculiar dietary craving of reindeer in the spring, when they kill lemming and mice with their forefeet and eat them, as well as birds' eggs and young. They have a particular craving for urine and compete successfully for early mushrooms with their herders. The habit of taking urine is not restricted to the reindeer but is practiced by the Chukchi reindeer people. The well-to-do reindeer owners purchase the dangerous *Amanita* fungi which are eaten for their intoxicating effects. The urine of the *Amanita* eaters is then imbibed by the less well-to-do herders. Reindeer also gnaw on old bones and, when they reach the sea, they have been observed to wade in and drink salt water. Although reindeer are able to absorb up to 78% of the carbohydrate intake, lichens as a group do not appear to be the most nutritious food. Nevertheless, experiments excluding lichens from their diet bring on diarrhoea, which may explain why even in summer reindeer eat lichens. The presence of lichen acids, closely related to tannic acid, apparently effects a binding action on the mucous membrane of the intestines of reindeer.

Other Economic Uses of Lichens

The uses of lichens as fodder for pigs, sheep and cattle, as food for humans and as industrial raw materials in brewing, distilling and dyeing have been described by the author in earlier papers. Several other applications and notes of interest not previously described are worth mentioning. One of these is the industrial extraction of "glucose molasses" (syrup) and "glucose" from lichens.

The method described by Kursanov and D'yachkov was developed in the war years 1942–1943, primarily because of a scarcity of beet sugar and the need to conserve grain and potato starch for the manufacture of alcohol for military purposes. The production unit consisted of three buildings, the factory covering 60 square meters, the storage shed with a volume of 240 cubic meters holding about 24 tons of dry lichens, and living quarters some 60 square meters in area. Exclusive of pickers, the plant was operated by 11 persons—a director, mechanic, accountant, watchman and six laborers—who processed 30 to 35 tons of lichens annually with a total daily production of 100 kilograms of glucose. The cost of harvesting the lichens was insignificant; the equipment, the fuel

(coal), the processing material—sulphuric acid, lime, activated charcoal and potash—and their transportation were more expensive items so that the cost of the finished product, in comparison to that of sugar beet, was reckoned as "quite high". It was suggested that by canning wild berries in season, the overall cost of the plant could be reduced.

The amount of glucose obtainable, in percent of the dry weight of the plants, varies considerably with species. Among the most widely distributed genera tested, the following species were the most productive: *Alectoria ochroleuca* (82%), *Cetraria islandica* (78%), *Cladonia mitis* (75%), *Usnea barbata* (74%), *Cladonia alpestris* (74%) and *Cetraria nivalis* (71%). Glucose molasses from *Cetraria islandica* is transparent with a brown tinge and is sweet with a caramel flavor. *Cetraria nivalis* glucose is much like that of the preceding species in quality but almost colorless. That of *Alectoria* clears best; the syrup is light-yellow but almost without foreign flavors. *Cladonia* species possess a bitterness which is difficult to eliminate, and for this reason their hydrolyzates are better applied to the production of alcohol or as a medium for growing food yeasts. Lichen glucose, which is described as "superior" to beet sugar, is also used for typographical purposes at a printing plant in Kirovsk.

The methods used in harvesting lichens are very similar to those employed by farmers in Norway for gathering lichens for fodder. The manufacturing techniques involve six steps, and after the fourth the process must be carried out to completion rapidly to avoid fermentation. First, the bitter taste is removed by steeping the lichen mass at a temperature of 12° C. in two changes of potassium carbonate dissolved in water; the first soaking lasts five hours, the second 12 hours. A solution made up of wood ash consists of seven times its volume of hot water, being equivalent to a 1–2% solution of pearlash. The mass is then rinsed in cold water and tested by taste. Hydrolysis, the second step, takes from eight to ten hours and is controlled at a temperature of not more than 100° C. Sulfuric acid is added in quantities equal to the weight of the dried lichen mass. When the filtration speed of the hydrolyzate through a paper filter approaches that of water, hydrolysis is completed. Neutralization is carried out by addition of 1.5 kilo of lime to one kilo of acid until the emulsion has the consistency of sour cream; temperature is maintained at 60° to 70° C. When neutralization reaches a pH of 5.5, which is determined by taste or with the aid of litmus dye (lichen dye), the process is taken to the next step, filtration. Filtration is accomplished in Dutch Filters at a temperature of 60° to 70° C. Although filtrates may vary in color, the best is described as transparent with a dark-yellow brown color. Following this step, the solution is cleared and bleached by adding activated charcoal in quantities of 0.5 to 1% by volume. The powdered charcoal is thoroughly stirred in with a paddle at a temperature of 70° to 80° C. The charcoal is removed by filtering or by centrifuge. The syrup should be mildly sweet, without bitterness or other flavoring, colorless, transparent or slightly yellowish. Excess water is removed by evaporation; to avoid charring, the recommended method is that used in making American maple sugar. Properly evaporated lichen molasses consists of 65 to 70% glucose with a density of from 38 to 40° Baumé. At this density the lichen molasses or glucose may be kept indefinitely in containers without spoiling.

Recent archaeological studies of Norse remains in Greenland which have revealed an abnormal wear of teeth as a result of trituration in comparison with contemporary Eskimo skulls, suggest

that during the terminal stage of the settlement the inhabitants may have been forced to subsist on lichens or/and seaweed. Recipes for the preparation of lichens for human use are found in the early Scandinavian literature. The survival value of lichens as food is, apparently, firmly established in the popular mind, notwithstanding information to the contrary. The author recently assisted in the preparation of a survival manual for the military from which all reference to lichens as emergency food was deleted. Authorities at a higher level considered this an oversight and very thoughtfully added the unnecessary data. It is striking that in the cultures of primitive arctic and subarctic peoples who suffered periodically from poor hunting years, there is no suggestion of the use of lichens during survival years. True, it has been recorded that the Central Eskimo of North Canada eat the lichen contents found in the stomachs of caribou and muskox, but this practice is allegedly unknown among the Western Eskimos of Alaska. The semi-digested mass is eaten as a delicacy, providing warm food immediately after the hunt or frozen food for later use, and may be the only source of plant food for many of the High Arctic Eskimos. The only verified and still prevalent use of lichens by the Alaskan Eskimos is as kindling material and in hunting the northern hoary marmot (*Marmota caligata broweri*). In the former case, *Cetraria richardsonii*, a loose, tumbleweed-like and

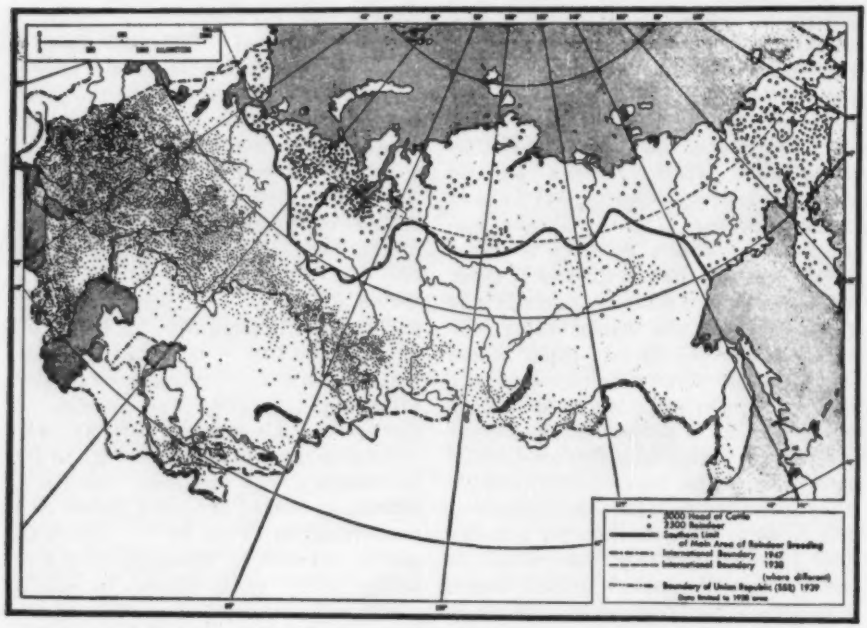

FIG. 6. Distribution and number of reindeer and cattle in the U.S.S.R. in 1938. Present activity in reindeer breeding east of the 80th meridian now extends south to about 50° N. latitude, corresponding to the approximate southern boundary of the Far North. (After Balzak, Vasyutin and Feigin).

coarse plant, is gathered for priming wood fires. In the latter instance the inland Nunamiut (Nunatarmiut) Eskimo locate the burrows of marmots on talus slopes by spotting the bright yellow lichen, *Xanthoria*. Growth of this lichen is materially aided through the animal's habit of evacuating and wetting in a circumscribed spot close to the hidden opening of its burrow, which is marked by the vivid yellow of *Xanthoria*. Talmachoff describes the Chukchi's stone lamps fueled with blubber oil ond provided with "reindeer moss" wicks; the usual type of wicks used among most northern people is commonly conceded to be *Sphagnum* or the cottony tufts of *Eriophorum*.

Mariners navigating through ice in northern waters might well take note of the observation made by that most discerning Norwegian lichenologist, Lynge, that it is possible to find open water in summer along the Northeast Greenland coast by checking for the bright-yellow and deep-orange discoloration caused by *Caloplaca* and *Xanthoria* on cliff faces and easily seen from afar in direct light. This ornithococrophilous vegetation is a landmark of rookeries, birds being attracted to the locality by nearby seasonal ice-free waters.

A word or two is in order on what reindeer, the most significant by-product of the plant resources of the Arctic, have meant to the development of some of the land regions of the North. As for the natural distribution of this husbandry, which is wholly a culture of the Old World, it may be noted that there it extends over an area where forests grow farther north and adjacent to the tundra. This may account, in part, for the fact that northern Asiatics live, for the most part, off the land and do not hunt on the sea ice to the same extent as the Arctic American and Greenland Eskimo. How the culture originated is not within the scope of this paper. Suffice it to repeat that, in addition to a rich forest fauna, the Asiatics had access to wood, a prime requisite for the construction of sleds and in the erection of their portable reindeer-hide shelters, or *chumy*, without which their pastoral existence would have been more difficult. The Nunatarmiut or Inland Eskimo of Alaska live in tents and are accustomed to hauling spruce poles from the upper reaches of the John River on the south slope of the Brooks Range before returning to the north entrance of the Pass. These poles are used for flooring and as uprights for their tents, and eventually for kindling. The Inland Eskimo, for the most part, lead a nomadic life, hunting caribou, wolves and bear, but mainly near their camps which are usually situated near mountain passes through which the migratory game funnel.

Since early times the Eskimo of the coast of Alaska have lived in communities close to the sea and have cooperatively hunted seal, walrus and whale. These hunting grounds were soon discovered by whalers whose predatory economy in the destructive exploitation of the above sea-mammal resources of the Eskimo partially induced the introduction of reindeer for the support of the natives. The failure of reindeer husbandry along the Arctic Coast was in part due to the sedentary habit and more attractive social winter life of the villages, and of a people accustomed to seasonal hunting. Their homes, many of which are now constructed of imported wood, were fixed and built of turf, reinforced with stone, drift wood and the bones of whales. The American Eskimo generally when travelling in winter used *igloos* or the *qarmat* which, though easily constructed, were always abandoned, and in summer lived in temporary skin shelters.

Before 1940, when new Soviet laws governing the use of land and water were promulgated, the Yakuts, the Tun-

gus, the Komi, the Nenets and the Chukchi were entirely dependent upon reindeer breeding. Other peoples, such as the Eveni or Lamuts, also engaged in raising reindeer, and among the Uryankhay and Soyots of Tuva it is still the livelihood. Since 1940, reindeer breeding has been collectivized and over 150 reindeer breeding stations have been established through the Far North. Research is being conducted on the nutritional values of lichens and various grasses, reindeer management, predator and insect (warble fly) control, selective breeding for draft or meat animals and acclimatization of stock. Some of the collective farms are reported to have experimental herds of 10,000 and 12,000 head. According to Zhigunov and Terent'yev, the income received from the use of reindeer for transport purposes was, on the average, for all rayony

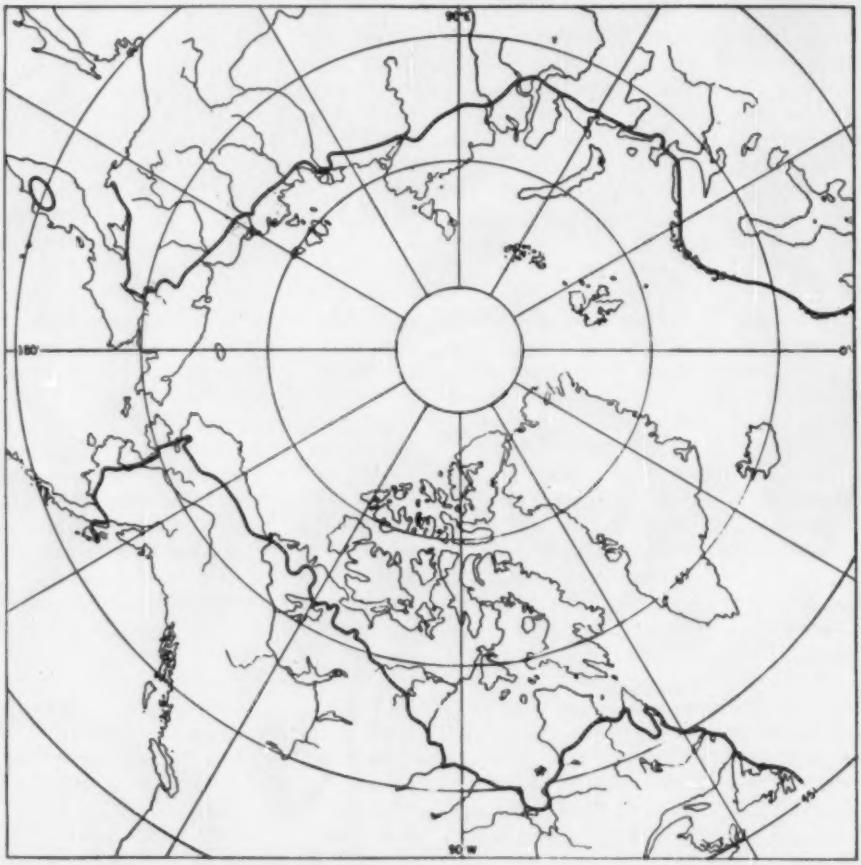

FIG. 7. The polar limit of tree-like conifers. (After I. Hustich). In the mountains of the Anadyr' and Penzhina basins, there is a widespread subalpine vegetation of Japanese stone pine (*Pinus pumila*), Manchurian alder (*Alnus fruticosa*) and shrubby Middendorff's birch (*Betula middendorffii*), with a great many lichens, extending as wooded tundra almost to Markovo.

of the Far North 17% of the total income. In some reindeer stations this was the principal source of revenue in exchange for services rendered in feeding and outfitting the transports. Reindeer transportation included the delivery of goods from ports and wharves along the northern sea route (Sevmorput') to settlements along the coast and deep into the taiga, and the transfer of meat, fish, hides, furs, mail, etc., from remote settlements to the principal centers of trade. During the Finno-Russian War and World War II, reindeer transports were essential in moving war supplies along some of the northern battle lines. The Norwegian herds were appropriated by the Germans who needed furs on the Russian Front. Not infrequently, when concentration-camp or war prisoners were being marched from Siberian railheads to remote camps, the night stops were gladdened by the appearance of reindeer sled-trains bearing rations and clothing. The revenue obtained by collective farms from trapping is in proportion to the number of reindeer available to help maintain the trap lines, while fishing operations are also increased with the aid of this draft animal.

Above all, the reindeer is a source of food, clothing and tenting material for native populations throughout Eurasia. The hides and meat have a ready market in Scandinavia and European Russia; in the former country, smoked and dried reindeer meat was unrationed during the last war. In parts of Krasnoyarsk Kray, Tobol'sk Okrug and Omsk Oblast, reindeer milk and cheese are widely consumed. Along the Arctic Coast the reindeer is the principal source of meat. Well tanned reindeer leather provides a high quality suède of importance in the manufacture of aeronautical, optical and precision instruments and in the hand and footwear industries. Fawn skins make beautiful light fur clothing. Reindeer hair, being hollow and resilient, makes the best type of insulation for sleeping bags and is also used in the manufacture of mattresses, upholstery and saddles. Reindeer wool, about 30% of the total fur, can be felted, knitted and woven into apparel of remarkable warmth. The antlers are made into boneware articles or are processed for glue and gelatin. Zhitkov remarked that reindeer were found on all the Arctic Islands north of Eurasia visited by man except on Kolguyev Island, and wild reindeer are still hunted in Asia. Depending on feed and climate, reindeer vary greatly in size and weight. In the taiga they are taller (2 meters) and heavier (180 kilograms). Here, as well as in Tuva Oblast', they serve as mounts and pack animals. The tundra varieties are generally of lighter build and are used as draft animals. Except for those broken to saddle or to draw loads, reindeer are never more than semi-domesticated and require constant herding to prevent their scattering by storms, predators, insects or raids by wild bull reindeer.

Conclusions

The practical utilization of the lichen fields of arctic and subarctic lands is a *sine qua non* in meeting the demands for an increased production of livestock and livestock products. That this is a solution envisioned to a problem of concern to more than the Arctic is attested by the recent introduction of reindeer into the Aleutians and other islands of the Bering Sea, into the highlands of Scotland, the mountains of Colorado, Patagonia and, reportedly, on Iles de Kerguelen. The South Georgia herds, introduced in 1911–1912, have flourished, providing sport and fresh meat for the Antarctic whalemen attached to the whaling station at Grytviken.

A concomitant of the introduction of cattle or sheep, where practical, is always the difficulty and expense of pro-

viding concentrate feeds and winter feed in general. Lichens offer a feed supplement useful only in the absence of normal fodder. Accessory problems are associated with shelter and the need for water in winter. The Lomen brothers have demonstrated the possibility of reindeer stock raising along rationalized lines, now being continued in the Soviet manner, in aiding the Alaskan and Canadian Eskimo, and the Lapps of Fennoscandia and Russia to attain a degree of self-sufficiency which cannot be achieved by seasonal haphazard hunting in the face of a steadily diminishing source of wild game. Grenfell's attempt to introduce reindeer husbandry to Labrador failed, and the virgin pastures of the Ungava Peninsula still lie unused. Manpower and markets as well as lichen pastures are necessary for the success of reindeer breeding; in the face of the present technological exploitation of the Arctic with its inducements of high wages and easy living offered to local labor in order to recruit the manpower required for the development of various projects, reindeer herding is being forced out—at least along the DEW Line.

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